3.18 WATER AND SEDIMENT QUALITY

This section describes existing conditions related to surface water, groundwater, and sediment quality in the Environmental Impact Statement (EIS) analysis area, which includes the project footprint, and areas adjacent to or downstream of—and potentially affected by—project elements. In addition to areas potentially affected by Alternative 1a, areas potentially affected by the other alternatives and variants are also assessed. Geochemistry at the mine site is described as it relates to the potential for release of chemicals into water from mining activities. Information on water and sediment quality criteria that are used to compare to existing and future conditions are provided in Appendix K3.18.

Water quality evaluation factors to be considered by the US Army Corps of Engineers (USACE) in making determinations under Clean Water Act (CWA) 404(b)(1) Subpart C include the following physical and chemical characteristics of the aquatic ecosystem. These are addressed in this section of the EIS as noted below:

- **Substrate—**Substrate includes sediment at the bottom of waterbodies, as well as wetland soils. Baseline characteristics of waterbody substrate (sediment) in the four project components are summarized below, and additional details are provided in Appendix K3.18. Baseline information on wetland substrate is provided in Section 3.22, Wetlands and Other Waters/Special Aquatic Sites, and Section 3.14, Soils. Removal and disposal of dredged marine sediment under Alternative 2—North Road and Ferry with Downstream Dams, and Alternative 3—North Road Only, are addressed in Section 4.18, Water and Sediment Quality.
- **Suspended Particulates/Turbidity—**Measurements of total suspended solids (TSS) and turbidity in water are summarized in the surface water quality sections of this chapter, and additional details are provided in Appendix K3.18.
- **Water Quality—**Water quality data are summarized in the surface water quality sections of this chapter, and additional details are provided in Appendix K3.18.
- **Salinity Gradients—**Salinity trends are described in this section under "Marine Ports," and additional details are provided in Appendix K3.18.

3.18.1 Mine Site Area

3.18.1.1 Geochemistry

Rock chemistry typically drives water quality, facility design, and water treatment requirements at hard rock mines (ADNR 2014). The open pit, bulk tailings storage facility (TSF), pyritic TSF, and water management ponds (WMPs) at the mine site pose the most significant risk to water quality because they expose fresh rock to oxidation and leaching processes that may generate acidic or neutral drainage containing leached metals that could impact water quality. The geochemistry of the rock that would be mined and exposed at the Pebble deposit is described in this section, followed by a summary of existing data for surface water, groundwater, and sediment at the mine site.

The Pebble deposit is a copper-gold-molybdenum porphyry deposit that was formed when older sedimentary and igneous rocks were intruded by a granitic magma laden with hot fluids carrying dissolved copper, gold, molybdenum, and silver, as well as quantities of rhenium and palladium. As the fluids cooled, concentrations of sulfide minerals such as chalcopyrite ($CuFeS_2$), molybdenite (MoS_2), and pyrite (FeS_2) hosting the copper, gold, molybdenum, and silver metals, precipitated in quartz veins and disseminated throughout the granitic intrusive and adjacent sedimentary and igneous rocks.

Geochemical Processes

In the natural environment, rocks are physically and chemically broken down to create soil layers through exposure to air and water in a process called weathering. During chemical weathering, minerals in the rocks react with air (oxidation) and water (dissolving into solution) to release some of their constituents (ions) into the surrounding environment. The ions that go into solution may be transported away by overland runoff, streams, and groundwater. Therefore, weathering processes in rock can have a large influence on water quality. If a mineralized deposit is buried beneath other rocks, sediment, or soil, it naturally weathers very slowly. However, when a mineralized deposit is exposed at the surface, weathering can increase substantially due to direct exposure to rain, snow, and air.

Both ore and non-ore rocks contain minerals that can produce acid during weathering. The most common acid-generating mineral is pyrite (FeS_2), which contains iron and sulfur. The sulfur in pyrite reacts with oxygen and water to form sulfuric acid (H_2SO_4). The resulting acidic water is known as acid rock drainage (ARD), which in turn further accelerates the weathering process. Metals and other potentially harmful constituents can also be released during weathering in a process called metal leaching (ML). Most metals are released more rapidly in acidic water; however, some other constituents, including metalloids such as arsenic, molybdenum, and selenium, and salts such as sulfate, can be released into the environment even if the water draining the rock has a neutral or basic pH (Smith 2007). Acid generation can be counteracted if there are minerals present that neutralize the acid, such as calcite. Neutralization occurs through a reaction of calcite with the sulfuric acid. In the presence of calcite and other neutralizing minerals, acidification is typically delayed until the neutralizing minerals are exhausted.

The purpose of geochemical characterization at the mine site is to identify the potential for the rocks in and surrounding the mineralized deposit to produce ARD and/or ML that could affect surface water and/or groundwater quality. The characterization process involves studies of the mineralogy of the rocks, the quantities of minerals with potential to generate or neutralize acid, the amounts of leachable constituents in the rocks, and the expected rates of weathering and release of the leachable constituents during mining and after mining ceases. Geochemical characterization was undertaken as part of environmental baseline studies over a number of years to evaluate the potential for ARD and/or ML for the project (PLP 2018a; SRK 2011a, 2018a, 2018c). A summary of the results of these studies follows, and additional details are provided in Appendix K3.18.

Geochemical Characterization

The objectives of the geochemical characterization program were to predict the weathering and leaching behavior of rock, tailings, and other materials that would be produced during mining and processing. Data produced from geochemical testing are used to predict the chemistry of waters that contact the rock exposed in the open pit, and the waste rock and tailings stored in the TSFs, and determine their ARD/ML potential.

Sampling and Testing Program—Samples for geochemical testing include representative overburden, rock cores, and metallurgical waste (tailings) samples from the Pebble east and west zones (PEZ and PWZ), and rock core samples from borings drilled in three proposed construction rock quarry areas. Samples were selected from the numerous exploration cores drilled to outline the deposit. A visual analysis was performed to confirm that samples were representative across the lithologic and geochemical variations observed in the deposit. Additionally, a data gap analysis was performed, and additional samples were manually selected to ensure a representative sampling pattern was used (SRK 2011a). A summary of the geochemical testing program is provided in Table K3.18-2. The samples included all the main Pebble deposit rock types and adjacent rock types that might be removed during mining. As of 2018, the program had included analysis of 1,023 rock samples from the Pebble deposit, and 26 samples of overburden materials. In addition, 64 tailings samples have been characterized, composed mostly of angular, pyritic, and tails from test processing of ore composites. To date, limited geochemical testing has been performed on the representative concentrate because possible designs for metallurgical processes are still at an investigative stage. Additional information pertaining to geochemical evaluation of samples and their representativeness of conditions at the mine site is provided in Appendix K3.18 and SRK (2019a).

The rock samples were tested using industry standard mineralogical and geochemical analysis techniques to assess the chemical and mineralogical makeup of rocks in the project area and evaluate the potential for the generation of ARD or leaching of metals into surface water or groundwater. Tests included mineral abundance, ARD potential, bulk chemical composition, and constituent mobility. Geochemical tests have included acid-base accounting (ABA), sequential net acid generation, shake flask extractions, meteoric water mobility, humidity test cells, subaqueous (saturated) leach columns, and on-site field weathering (barrel and bag) tests to evaluate rates of oxidation, acid generation, acid neutralization, and element leaching. The geologic settings between the PEZ and PWZ zones are comparable, with the same mineralizing system and the same host rocks. For this reason, use of samples from both the PEZ and PWZ provides the most representative and conservative assessment of ARD/ML potential because PEZ samples tend to be more acidic and have higher metal contents (SRK 2018f). Selected geochemical data are summarized in data tables in Appendix K3.18, and described below.

Acid-Generating Potential—In some mineralized deposits, rock type alone can be a good indicator of whether a rock would potentially produce ARD and/or ML. There are two main geological divisions at the mine site. The minable mineralization is hosted by sedimentary and plutonic rocks of pre-Tertiary age (older than 66 million years ago). After the pre-Tertiary mineralization, those rocks were partially eroded, then covered by other sedimentary and volcanic rocks later in the Tertiary (Paleogene and Neogene periods) (see Section 3.13, Geology). The later Tertiary age rocks at the mine site generally do not contain copper, gold, or other metals that would be economically viable to recover (SRK 2011a; PLP 2018a).

A summary of ABA data is provided in Table K3.18-3. ABA testing has determined that the pre-Tertiary mineralized sedimentary and plutonic rocks at the mine site are predominantly potentially acid generating (PAG). PAG waste rock has been defined by PLP as any rock with a neutralization potential (NP)/acid-generating potential (AP) ratio equal to or greater than the site-determined NP/AP criterion of 1.4 (PLP 2018a). The AP of these rocks is relatively high because they contain several percent pyrite, as indicated by total sulfur contents greater than 1 percent, and they have limited NP. The distribution of pyrite (and consequently AP) was found to be influenced by the hydrothermal alteration zones overprinted on the deposit. More details and uncertainties involved the development of a site-specific NP/AP ratio at the mine site are provided in Appendix K3.18. Because inherent uncertainty exists in the study of NP/AP ratios, a recommendation is provided in Appendix M1.0, Mitigation Assessment, to consider more conservative (higher) ratios as mine planning and design progress.

In contrast, the majority of the Tertiary age rocks that compose the cover and overburden materials at the mine site are considered non-PAG because they have less than 1 percent pyrite, low total sulfur concentrations, and excess NP because carbonate minerals are abundant. However, a small proportion of the Tertiary age volcanic rocks were found to be PAG.

Weathering and Leaching Rates—To develop an understanding of weathering and leaching processes that might affect rocks exposed during mining (e.g., pit walls and stockpiled waste rock and tailings), additional laboratory and field geochemical tests were conducted. Laboratory tests included humidity cell, subaqueous (saturated) column, stored bag, and field barrel tests. Humidity cell test data obtained for periods up to 8 years allow interpretation of long-term acid generation potential and neutralization rates as the rocks are oxidized and leached during wet and dry cycles. Humidity cell test results were used to confirm ABA criteria for segregating PAG from non-PAG rocks and waste, based on the NP/AP ratio. The ABA and humidity cell data indicate that PAG and non-PAG rocks can be distinguished using an NP/AP ratio of 1.4 (PLP 2018a), and are applicable to pre-Tertiary, Tertiary, and overburden materials. The discrete site-specific PAG criterion of 1.4 was determined though analysis of the molar release rate obtained from humidity cell tests (PLP 2018a). The molar release rate is an equivalent to the NP/AP criteria, and can be examined to determine the site-specific criterion for potential acid generation (Day et al. 1997). If the molar release ratio is greater than the NP/AP ratio, the waste rock has the potential to generate acid (SRK 2011a). PLP (2018a: Figure 11-28) depicts the molar ratio data from humidity cell tests used to determine site-specific NP/AP criterion of 1.4.

Humidity cell tests also help to estimate the potential lag or delay in the onset of ARD using the sulfide oxidation and release rates and pH profiles derived from the tests. The lag or delay in the onset of ARD occurs because acid-neutralizing minerals (e.g., calcite, feldspars, and micas) are not depleted instantly as acid is formed, but are consumed at different rates depending on their reactivity and abundance. Once the acid-neutralizing minerals are depleted, ARD may be initiated. Results show that pre-Tertiary rocks with low NP/AP ratios (less than 0.3) have little neutralization potential and are estimated to generate acid within 1 to 6 years (SRK 2018a). Pre-Tertiary rocks with NP/AP ratios of 1 have higher neutralization potential, which delays the estimated onset of acid generation from 8 to 20 years (SRK 2018a). These estimated times to onset of ARD are considered underestimates, because they are based on data developed under ideal, controlled laboratory conditions. Actual conditions in the field, with colder temperatures and long winters, are likely to be less conducive to acid formation, and further delay the onset of ARD. The effect of temperature conditions on the rate of oxidation is further discussed in Appendix K3.18. Paste pH results for aged rock cores stored at the site suggest that acidification may be delayed up to 40 years for 95 percent of the pre-Tertiary mineralized rock (SRK 2011a). Given differences in the various test conditions described above, laboratory and field tests suggest that oxidized pre-Tertiary mineralized rock may take in the range of years to several decades for acidification to occur.

Element release rates determined from kinetic (humidity cell, barrel, saturated column, and stored bag) tests, which were mostly performed on filtered samples, were mainly a function of leachate pH rather than the element content of the samples (SRK 2011a). Use of dissolved (filtered) concentrations are reasonable because element release is characterized by the chemical breakdown (dissolution) of minerals to form soluble species and secondary minerals. Because these processes occur in very slow-moving contact water, suspension and transport of particulates is not expected. Leaching of copper was found to accelerate as pH decreased; therefore, the potential for release of many metals is linked to the potential for acid generation, which is assessed using ABA data. However, the release of some elements—arsenic, molybdenum, and selenium—can be environmentally significant under circumneutral pH, as described in SRK (2011a). Tests on some samples of Tertiary rock showed elevated leaching of these elements under non-acidic conditions. Data analysis from the various geochemical tests performed yielded consistent results. Leaching data from humidity cell tests, barrel tests, and shake flask tests performed on samples collected in both the PWZ and PEZ were used to develop geochemical source terms for predictive water quality (SRK 2018c, f). To be conservative, the source term concentrations were developed at the 95th percentile. In general, the 95th percentile release rates for Tertiary and Cretaceous rocks were similar under basic conditions, and significantly greater when using combined PWZ and PEZ datasets, compared to samples from the PWZ only (SRK 2019a, Figure 1). Additional information regarding how the data were used in water quality modeling is provided in Section 4.18, Water and Sediment Quality.

Tailings—Ore processing based on a conventional flotation process to recover chalcopyrite and molybdenite, the primary copper and molybdenum minerals, followed by treatment of pyrite to recover gold, would result in a low-sulfide bulk tailing concentrate and a high-sulfide (pyrite-rich) tailing concentrate, respectively. Metallurgical process testing has produced a range of representative tailings products. Geochemical testing of 64 tailings samples indicates that the most volumetrically abundant product, bulk tailings, which would be produced under most of the processing approaches being considered, typically contains low to moderate total sulfur. Bulk tailings can be categorized as non-PAG if the total sulfur remains below 0.2 percent. Under equivalent conditions (including grain size and exposure to oxidizing conditions), the ARD potential for the bulk tailings is lower than that of mineralized rock, because most of the sulfur is removed to recover the economic minerals and separate out the pyritic tails while concentrating neutralizing minerals in the bulk tailings. Element leaching from the rougher tailings occurred at low rates, and unfiltered process supernatants were found to contain low levels of potential constituents relative to water quality standards. The pyrite and gold plant tailings have higher sulfide contents; are often classified as PAG; and leach metals at higher rates. Appendix K3.18 provides additional information on the geochemical characteristics of the tailings and supernatant.

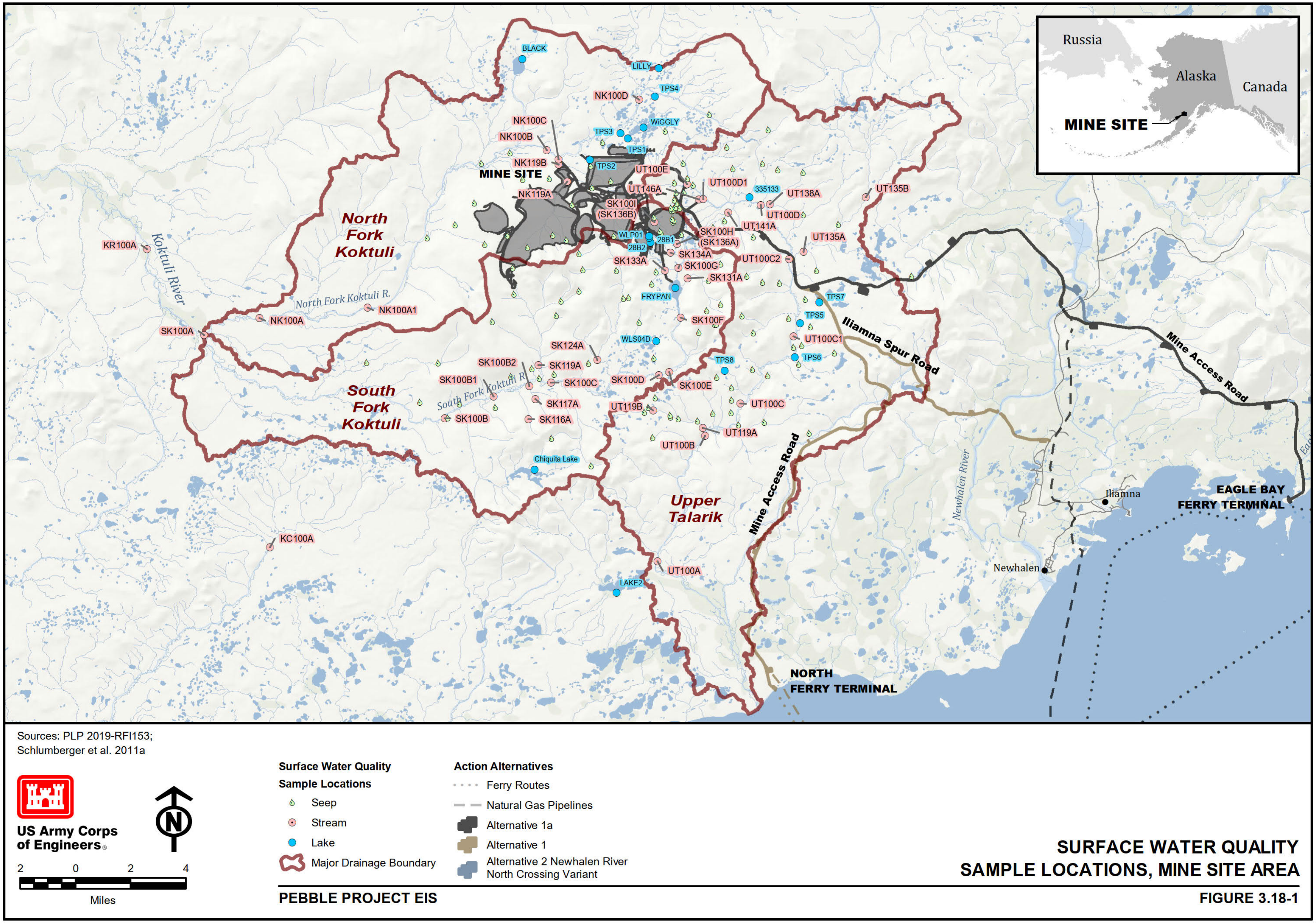
Open Pit Block Model—Because of the geochemical variability in the rocks, assessment of impacts resulting from geochemical processes requires consideration of the disposition and fate of the material that would be mined each year. The annual area and rock types mined can be estimated using a geologic block model (i.e., a computer model that shows the three-dimensional location of each type of rock and the likely order of mining). The geologic block model could be updated in the future to incorporate geochemical data so that mineralized and waste rock can be managed appropriately as mining proceeds. During mining, rock materials would be assessed using the block model to determine whether the mined rocks are PAG or non-PAG, and whether the mined material would be processed and disposed as tailings, or not processed and set aside as waste rock. Further information regarding the block model is provided in Appendix K3.18.

Based on the results obtained from the geochemical characterization studies, the majority of the rocks that would be expected to be mined from the PWZ do not have the potential for acid generation, and could be considered substantially acid neutralizing. However, some rocks do have the potential to leach certain constituents under circumneutral pH; mainly, arsenic and selenium. These results, and their influence on the existing baseline water quality at the mine site, are discussed in more detail in the next few sections.

3.18.1.2 Surface Water Quality

The Pebble deposit and project area are in the headwaters of the Upper Talarik Creek (UTC) and South Fork Koktuli (SFK) River drainages, and adjacent to the headwaters of the North Fork Koktuli (NFK) River drainage. The NFK River is on the northern side of the project area. The Kaskanak Creek (KC) drainage lies south of the SFK River drainage.

Sampling Program—Water quality studies were conducted by Schlumberger et al. (2011a) and ERM (2018a) to quantify chemical and physical parameters that describe the quality of the water at the mine site and surrounding areas that could potentially be impacted by the alternatives. Water quality data were collected for rivers, lakes, and seeps in the project area, and throughout a 965-square-mile area that includes the NFK River, SFK River, and UTC (Figure 3.18-1).



SURFACE WATER QUALITY SAMPLE LOCATIONS, MINE SITE AREA

PEBBLE PROJECT EIS

FIGURE 3.18-1

A comprehensive network of sampling stations was established in the project area for sampling surface water from streams, lakes, and seeps. Stream samples were collected from 44 locations during 50 sampling events from April 2004 through December 2008 (Schlumberger et al. 2011a). These included seven locations in the NFK, 18 in the SFK, and 15 in the UTC watershed; water quality sampling was conducted at most locations on a monthly or quarterly basis (Schlumberger 2011a, Table 9.1-2). Lake and pond samples were collected from 19 lakes once or twice per year in July and/or August during 2006 and 2007; these were collected as near-surface grab samples. Seep samples were collected from 11 to 127 sample locations (depending on the year), two to five times per year between March and November. Surface water samples were collected using a combination of grab and depth-integrated sampling. Grab sampling was used when necessary for safety in high-flow conditions, in shallow streams, and during freeze-over periods (Schlumberger et al. 2011a).

Altogether, between 2004 and 2008, over 1,000 samples were collected from streams, more than 600 samples from seeps, and approximately 50 samples from lakes. Additional samples were also collected during the supplementary water quality study period, which occurred from 2008 to 2013 (ERM 2018a).

Several tables are provided in Appendix K3.18 showing a summary of surface water quality data compared to criteria for waterbodies most pertinent to potential future impacts at the mine site. These include data for NFK, SFK, UTC, and Frying Pan Lake (Table K3.18-7 through Table K3.18-10). Additional water quality details on seeps and other lakes and streams in the mine site study area are provided in ERM (2018a: Tables 9.1-15 through 9.1-24) and Schlumberger et al. (2011a, Tables 9.1-31 through 9.1-36), and are incorporated by reference into the discussion below.

Overview of Sampling Results—The results of these analyses indicate that the baseline surface water resources can generally be characterized as cool, clear waters with near-neutral pH that are well-oxygenated, low in alkalinity, and generally low in nutrients and other trace elements. Water types ranged from calcium-magnesium-sodium-bicarbonate to calcium-magnesium-sodium-sulfate. Water quality data occasionally exceeded the maximum criteria for concentrations of various trace elements in some individual sample measurements; however, in no instance did the mean concentration of trace elements exceed the most stringent water quality guidelines. Cyanide was occasionally present at detectable concentrations in a limited number of samples. Cyanide detected in those samples is believed to be of natural origin, based on the distribution and lack of anthropogenic sources. Cyanide can occur naturally as a product of anabolism in some plants, bacteria, and fungi (CDC 2006). Additionally, there were consistently detectable concentrations of dissolved organic carbon. No detectable concentrations of petroleum hydrocarbons, polychlorinated biphenyls, or pesticides were found.

Some differences in water quality between watersheds and trends in water quality along streams were noted, based on repeated monthly or quarterly sampling at most locations in the NFK, SFK, and UTC over the 5-year sampling period. These are summarized below and in tables in Appendix K3.18. Higher concentrations of copper, molybdenum, nickel, zinc, and sulfate were present in SFK than in NFK, consistent with SFK's proximity to the Pebble deposit area. Total dissolved solids (TDS), pH, sodium, alkalinity, hardness, nitrogen (nitrate+nitrite), and nickel concentrations were greatest in the UTC drainage. The uppermost reach of UTC passes through a portion of the general deposit area, and had significantly higher concentrations of these naturally occurring constituents than in NFK. TSS, potassium, chloride, iron, and arsenic concentrations were highest in KC, while cadmium and lead concentrations were highest in the NFK drainage. These characteristics of KC and NFK likely indicate that these parameters are unrelated to the deposit area, and represent water quality signatures that are distinct from the other drainage areas.

The following paragraphs discuss some of the specifics of the sample results and trends observed in the NFK, SFK, and UTC. Data summaries for these streams are provided in Table K3.18-7 through Table K3.18-9, and trend analysis data in Table K3.18-14 through Table K3.18-16.

Total Dissolved Solids—The mean levels for TDS in streams, by watershed, ranged from 37 to 53 milligrams per liter (mg/L), which is 10 percent or less of the most stringent Alaska Department of Environmental Conservation (ADEC) water quality maximum criterion. Of the three streams that originate close to the deposit area, UTC and SFK had significantly higher TDS levels than NFK. Furthermore, a decrease in TDS levels with distance along the stream was more pronounced in the SFK and UTC watersheds than in the NFK watershed. Higher TDS in the UTC and SFK watersheds with decreasing trends downstream was expected, because the deposit area lies within their watersheds, and the oxidation of sulfide minerals associated with the deposit would release dissolved solids. The mean levels for TDS in lakes and seeps were similar to those for streams, with values of 49 and 42 mg/L, respectively.

Total Suspended Solids and Turbidity—Mean TSS values ranged from 1.19 mg/L to 3.21 mg/L in the NFK and UTC, respectively. The highest value for TSS was in KC, and the lowest was in the NFK. Because there is no Alaska water quality criterion for TSS, these values were compared to an effluent limitation guideline (ELG) in 40 Code of Federal Regulations Part 440 Subpart J (see Table K3.18-1). Mean TSS values did not exceed this criterion for any rivers in the mine site area; however, at least one exceedance was recorded in a sample collected at the UTC. The mean for TSS in lakes and seeps was similar to that for streams.

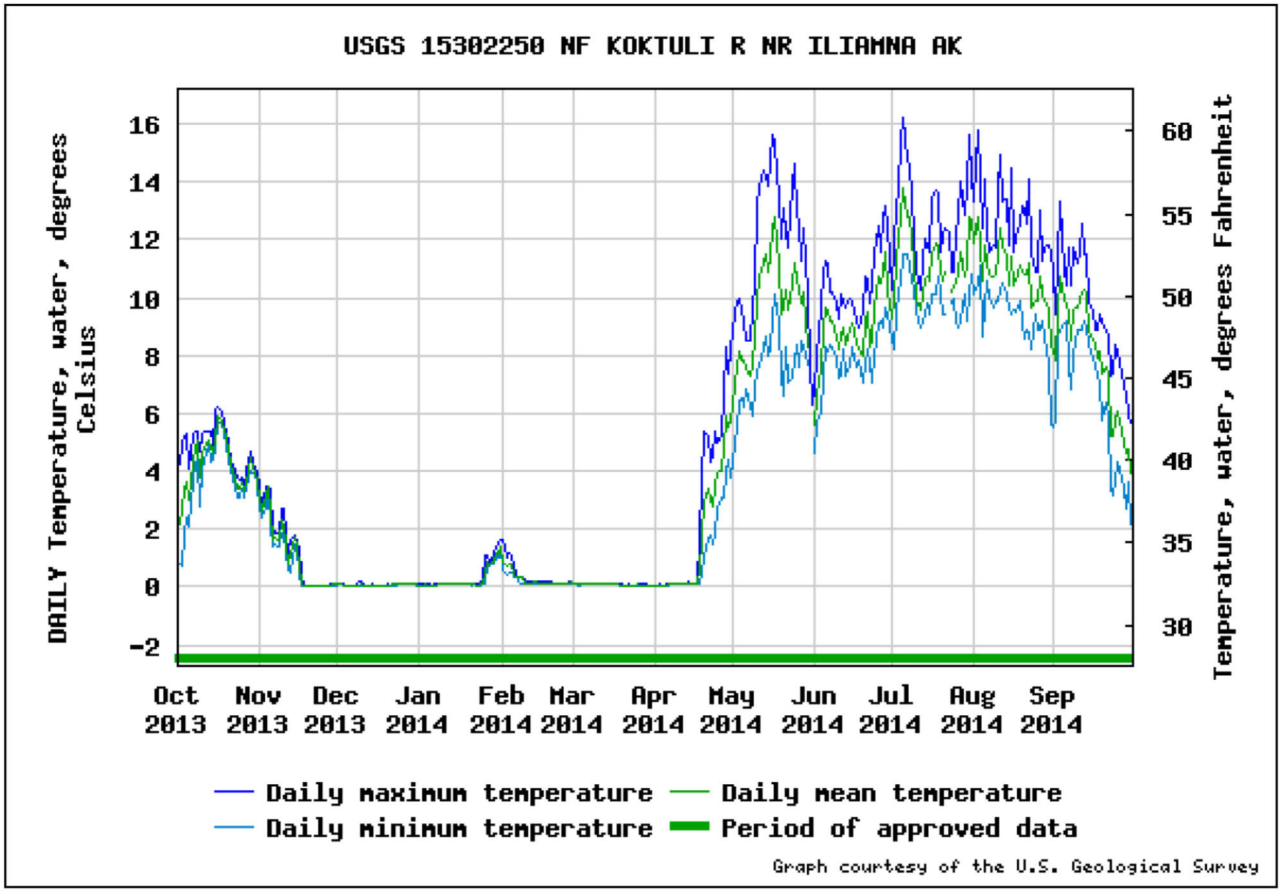
pH—The pH values in surface water were close to neutral. The mean pH for streams by watershed ranged from 6.7 to 7.0. The mean pH values for lakes and seeps were 7.2 and 6.5, respectively. Because of the exposed Pebble deposit and seasonally fluctuating groundwater conditions in the area (see Section 3.17, Groundwater Hydrology), it is possible that the oxidation of sulfide minerals releases acid in this area; however, based on the mean pH data, carbonate minerals may be providing some pH buffering. Although the mean pH values fell within the range for pH specified in the most stringent ADEC criteria (6.5 to 8.5), some individual water quality samples did not meet the water quality criteria for pH. Recorded pH values ranged from 3.31 to 9.33, with the lowest pH recorded in the NFK and the highest recorded in UTC. The frequency of this trend in seeps was at least double that of streams, depending on the watershed, suggesting that contact with local rock could be a contributing factor to pH outside of the 6.5 to 8.5 range.

Alkalinity—The alkalinity of the surface water samples was low. Mean alkalinity for streams, by watershed, ranged from 17 to 32 mg/L. Mean alkalinity for lakes and seeps was 19 and 23 mg/L, respectively. Alkalinity was the parameter that was most frequently detected outside the range of the most stringent ADEC criterion. In all, 43 percent of all surface water samples were below the minimum criteria for alkalinity, as specified by the ADEC. The frequency with which alkalinity values for lakes and seeps were below the minimum criterion was 10 to 20 percent higher than the frequency for streams.

Temperature—Mean water temperature in streams ranged from 4.0 to 4.8 degrees Celsius (°C), depending on the watershed. The standard deviation of temperature values measured in each watershed was approximately equal to the mean of the values, indicating a high level of variability. Lakes in the mine site area were considerably warmer, with a mean temperature of 12°C, and seeps slightly cooler, with a mean temperature of 3.4°C. Lake sample collection in July and August (compared to seep sample collection in March through November) could account for some of these temperature differences, and lake temperatures are expected to be cooler in other seasons.

Temperature recording at the US Geological Survey (USGS) gaging stations began in October 2013. Although long-term water temperature trends are not available, these may vary as a subdued expression of long-term air temperature trends. Mean annual temperature trends in the region indicate that air temperatures have increased approximately 3°C over the past 50 to 60 years (Knight Piésold 2012, 2018a); trends that are predicted to continue into the next century (SNAP 2018). Figure 3.18-2 shows daily water temperatures in the NFK River.

USGS Water-Year Summary for Site USGS 15302250



Source: USGS 2018

US Army Corps of Engineers

DAILY WATER TEMPERATURES IN NFK RIVER

PEBBLE PROJECT EIS

FIGURE 3.18-2

Dissolved Oxygen—Dissolved oxygen (DO) concentrations in streams were very similar in all watersheds, with mean concentrations that ranged from 9.7 to 9.89 mg/L. These values are close to the theoretical solubility of oxygen of 12.3 mg/L at 900 feet above mean sea level (amsl), and a water temperature of 4°C. Although most samples indicated high DO, 7 percent of the samples had DO concentrations lower than the most stringent ADEC minimum criterion.

Major Ions—Water type can be characterized by the presence and predominance of specific ions, including anions and cations. The water type of most samples from streams in the mine site area ranged from calcium-magnesium-sodium-bicarbonate to calcium-magnesium-sodium-bicarbonate-sulfate. The cation composition was dominated by calcium, and was relatively consistent. The anion composition had a wider range, with most stream samples being dominated by carbonate. The average water type of the lakes and seeps was generally the same as the streams; however, the seeps had a slightly greater range of water types, and the distribution of water types was slightly different. Specifically, the seeps included samples with a higher proportion of sulfate; and the samples also were distributed more evenly across the spectrum of anion composition, rather than being weighted toward the bicarbonate end of the spectrum.

Nutrients—Nutrients, which included total ammonia, total nitrogen (nitrate+nitrite), total phosphorous, and orthophosphate, had generally low concentrations, especially in lakes and seeps. Orthophosphate was generally not present at detectable levels, with one exception in the KC watershed. Total ammonia was detected in 19 to 36 percent of surface water samples, and mean concentrations ranged from 0.03 to 0.05 mg/L, depending on source (streams, lakes, or seeps). Nitrogen and phosphorous were detected in 66 to 98 percent of surface water samples, depending on the sample source. Mean concentrations of nitrogen ranged from 0.1 to 0.3 mg/L, and mean concentrations of total phosphorous ranged from 0.02 to 0.04 mg/L. None of the nutrient concentrations exceeded the most stringent ADEC maximum criterion. The coefficients of variation for nutrients were high compared to most other parameters; often in the range of 1 to 2.

Trace Elements—The trace elements aluminum, antimony, arsenic, barium, cadmium, copper, iron, lead, manganese, molybdenum, mercury, nickel, and zinc were detected in surface water grab samples, although at low concentrations. The frequency of detection depended on the watershed, and on whether the sample was collected from a stream, a lake, or a seep. Total and dissolved aluminum, barium, copper, iron, manganese, and molybdenum were typically the most frequently detected trace elements in the streams and lakes; the frequency of detection generally ranged from 85 to 100 percent, depending on sample source (streams, lakes, or seeps). The most frequently detected elements in the seeps were generally the same as those for the streams and lakes, but the frequency of detection was lower in the seeps (53 to 99 percent, rather than

Environmental baseline studies established that metals concentrations are generally below the most stringent State water quality criteria. However, the EIS analysis area does contain natural variance, and exceedances of State water quality criteria do naturally occur in surface waterbodies. For example:

In the SFK:

- Average copper concentrations in upper reaches of the SFK (Station SK100G) exceed the State water quality criteria.
- Elevated copper concentrations in the upper reaches of the SFK at this location are likely the result of close proximity to the copper ore body.
- Concentrations of copper in the SFK decrease downstream.

In the UTC:

- Baseline concentrations of nickel and arsenic in the UTC are roughly two and three times that of the NFK or SFK, respectively.
- Concentrations of nickel and arsenic are likely the result of bedrock geochemistry and natural processes involving the release of metals.

85 to 100 percent). Exceptions to this general pattern included a frequency of detection for total and dissolved arsenic in KC of more than 98 percent. The trace elements arsenic, lead, nickel, and zinc had an intermediate frequency of detection in most waters sampled, with the exception of zinc, which had a higher frequency of detection (98 percent) in lakes. Cadmium had the lowest frequency of detection.

Mercury was infrequently detected in samples, and was typically below the method reporting limit (MRL) and method detection limit (MDL), suggesting that baseline mercury concentrations are low. More than 1,400 samples were tested for mercury in the NFK, SFK, and UTC; mercury was below the MDL or MRL in approximately 95 percent of samples. MDLs for mercury ranged between 0.294 and 5 nanograms per liter (ng/L), and roughly 85 percent of samples analyzed had an MDL of 1.5 ng/L or less. The most frequently used MDL was 1.5 ng/L, which was the MDL for approximately 50 percent of samples analyzed (ERM 2018a). Although mercury was not typically detected, the MDLs and MRLs suggest that baseline mercury concentrations are below 5 ng/L, and likely below 1.5 ng/L, which is eight times less than the most stringent water quality criteria for mercury (12 ng/L, Table K3.18-1). Of the approximately 5 percent of samples where mercury was detected above the MDL and MRL, concentrations ranged from 0.001 ng/L to 12.2 ng/L across the NFK, SFK, and UTC.

Some trace element concentrations in stream samples exceeded the most stringent ADEC maximum criteria. These are described below in relationship to watersheds (trend analyses for data in individual watersheds are provided in Appendix K3.18):

- Copper from the SFK watershed exceeded the water quality criterion most frequently, with total and dissolved copper exceeding the criterion in 42 and 34 percent of samples, respectively. In contrast, copper had one of the lowest frequencies of exceedance in other watersheds. The relatively high frequency of exceedance in the SFK watershed is probably related to proximity of the deposit.
- Total aluminum exceeded the most stringent ADEC maximum criterion in 12 to 22 percent of the stream samples from the SFK, UTC, and KC watersheds; and in 6 percent of the samples from the NFK watershed. In contrast, dissolved aluminum exceeded the criterion in only 1 percent of the stream samples, and only in the UTC watershed; therefore, aluminum exceedances seem to be almost exclusively associated with suspended solids.
- Total lead exceeded the most stringent criterion in 8 to 16 percent of the stream samples, and was generally the next most frequently exceeded criterion after total aluminum. Dissolved lead exceeded the criterion in 1 to 6 percent of the stream samples, and was second only to copper for frequency of exceedance for dissolved elements.
- Total manganese exceeded the criterion in 15 percent of stream samples from the SFK and UTC watersheds, in 3 percent of the samples from the NFK watershed, and in none of the samples from the KC watershed. Similar to aluminum, manganese exceedances appear to be associated with suspended solids.
- Concentrations of total antimony, cadmium, iron, mercury, and zinc for the stream samples rarely exceeded the criteria (0.3 to 4 percent).
- In samples from seeps, exceedances of the most stringent maximum criteria included total and dissolved aluminum (17.2 percent total and 22.94 percent dissolved), total and dissolved copper (30.51 percent total and 42.78 percent dissolved), total and dissolved iron (4.61 percent total and 4.91 percent), total and dissolved nickel (23.21 percent total and 23.58 percent dissolved), total and dissolved lead (17.00 percent total and 36.31 percent dissolved), total and

dissolved cadmium (33.14 percent total and 42.78 percent dissolved), total and dissolved silver (14.34 percent total and 34.82 percent dissolved), total and dissolved zinc (11.03 percent total and 31.37 percent dissolved), and dissolved manganese (17.86 percent).

Cyanide was occasionally detected in the surface water samples. Total cyanide was detected in 2 to 15 percent of all samples, depending on sample source (streams, lakes, or seeps), and weak acid dissociable cyanide was detected in 5 to 13 percent of all samples. Concentrations of weak acid dissociable cyanide in samples were compared with the most stringent ADEC maximum criterion, and exceeded this criterion in 1 to 3 percent of the stream samples, depending on the watershed. Cyanide detections are believed to represent natural conditions, based on a lack of documented anthropogenic sources in the area. Cyanide ions can be generated naturally during biogenic processes of higher plant bacteria and fungi (Mudder and Botz 2000). Although cyanogenic compounds occur naturally in certain bacteria, fungi, algae, and higher plants, the most significant natural source of free cyanide in the environment is from hydrolysis of cyanogenic glycosides in higher plants (Halkier et al. 1988; Lechtenberg and Nahrstedt 1999; Vetter 2000; Zagrobelny et al. 2004).

Dissolved organic carbon was detected in 93 to 100 percent of the stream samples, and the mean concentrations ranged from 1 to 2 mg/L, depending on the watershed.

Concentrations of petroleum hydrocarbons, volatile and semi-volatile organic compounds, polychlorinated biphenyls, and pesticides were not detected.

3.18.1.3 Groundwater Quality

Mine Site Monitoring Wells—A total of 77 groundwater monitoring wells with depths up to 200 feet below ground surface was installed in the project area. Two additional drillholes (DH-8417 and GH10-220) were used for groundwater sampling in deep bedrock in the deposit area at depths ranging from 210 to 4,050 feet. Table K3.18-17 provides a list of wells completed in and outside of the Pebble deposit area, along with depth and bedrock lithology. The location of the wells is shown on Figure 3.17-2. The results of groundwater quality testing are summarized in Table K3.18-18, and discussed below based on mean values for wells grouped by lithology (ERM 2018a). These data were used to predict the water quality of pit dewatering water going to water management ponds, and influent to the water treatment plants (see Section 4.18, Water and Sediment Quality).

Groundwater samples from depths of 200 feet or less were characterized by mean levels of TDS ranging from less than 90 mg/L to over 150 mg/L (higher in bedrock wells); mean pH values between 4.4 and 7.3; mean DO concentrations ranging from 2.6 to 9.1 mg/L; and mean concentrations of dissolved trace elements above the most stringent ADEC water quality maximum criteria for several constituents (aluminum, copper, iron, lead, and manganese).

Concentrations of TDS in groundwater generally decreased with distance from the deposit area, and results from deep drillhole DH-8417 (mean of 835 mg/L) suggest that concentrations of TDS increase with depth (Knight Piésold 2018a). Monitoring wells MW-14D in the SFK watershed and P08-69D in the NFK watershed were the only wells showing a relatively high TDS level that was not consistent with this general pattern. Although data from well MW-14D are somewhat anomalous, they could be interpreted to suggest that the deposit has influenced groundwater quality.

Most of the groundwater samples had a composition that ranged from calcium-bicarbonate to calcium-magnesium-bicarbonate and calcium-sodium-bicarbonate. Some samples from relatively close to the deposit area had a higher proportion of sulfate, suggesting that the groundwater in this area is influenced by oxidation of the sulfide minerals that are associated with the deposit. As the sulfide minerals oxidize, iron, sulfuric acid, and probably trace elements are released; and the acid is neutralized by carbonate minerals such as calcite and dolomite, which release calcium, magnesium, manganese, carbonate, and usually some trace elements. This series of geochemical reactions increases the concentration of TDS and the proportion of sulfate in the groundwater.

Although sulfides appear to be oxidizing locally in the Pebble deposit area, the groundwater is not acidic overall. The lowest mean pH value of 4.4 was recorded at only one well in shallow bedrock. In the remaining wells, mean pH values ranged from 6.7 to 7.9, indicating broadly that the groundwater is not acidic. Eight wells (six completed in overburden, two in bedrock) had mean pH values greater than 7.0, and three of these wells (all completed in overburden) had the highest mean TDS concentrations observed.

The DO measured in the groundwater was generally high. Twenty-seven wells had mean DO concentrations of 8 mg/L or greater. Wells with relatively high TDS, measured in filtered samples, also generally showed relatively high concentrations of arsenic, barium, and molybdenum compared with other wells in the analysis area. All of the wells with more than two trace metals at relatively high concentrations were closer to the deposit area.

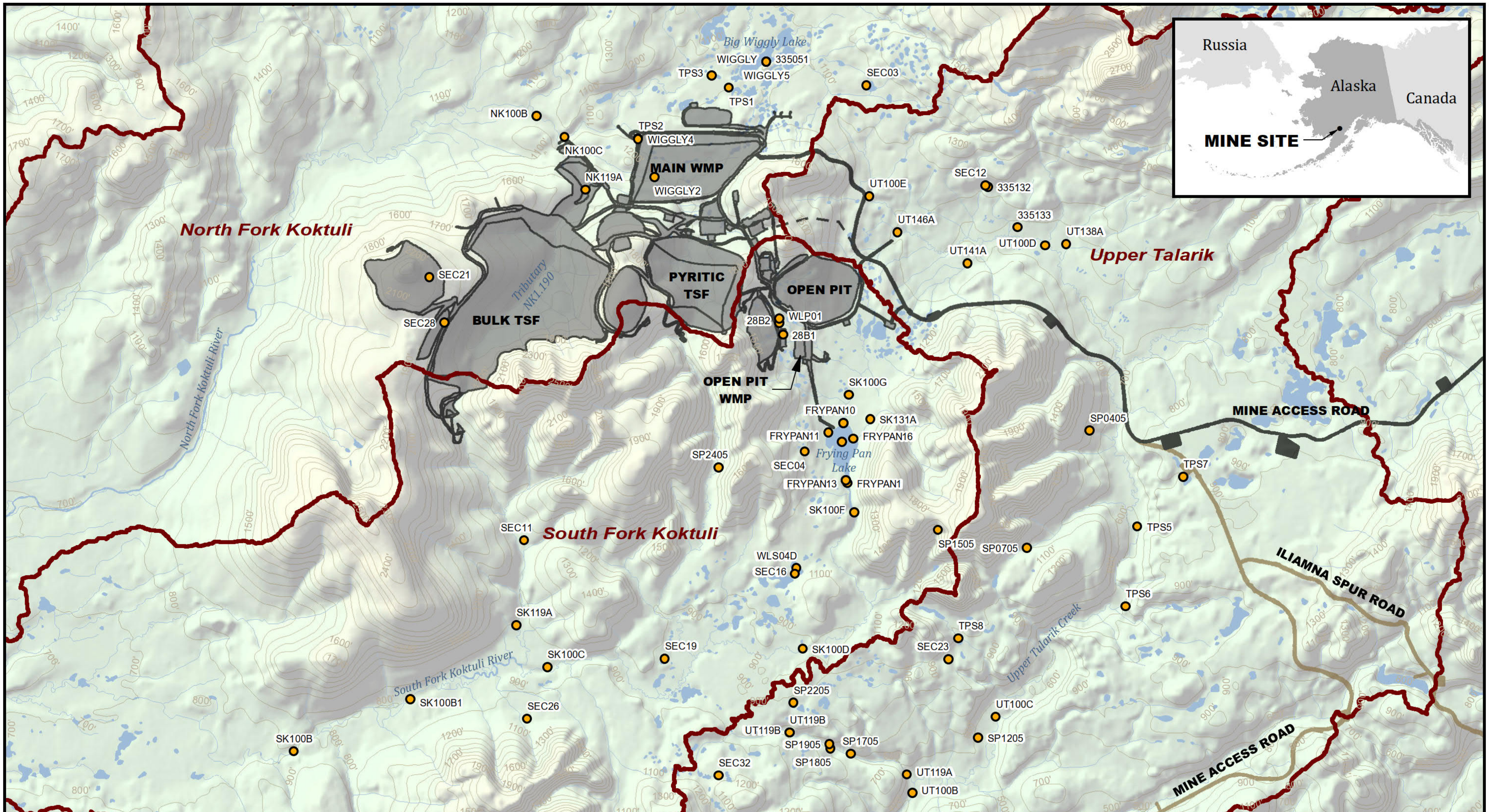
Some differences in concentrations were observed with depth, as indicated by wells completed in overburden versus those completed in bedrock (see Table K3.18-18). Specifically, concentrations of antimony, arsenic, copper, iron, manganese, and molybdenum tended to be higher in wells completed in bedrock than in wells completed in overburden. Conversely, concentrations of DO and nickel tended to be lower in bedrock wells than in overburden wells.

Drinking Water Protection/Drinking Water Wells—Drinking water sources are regulated by federal and state laws and regulations; mainly, the Safe Drinking Water Act (SDWA). Under the SDWA, the US Environmental Protection Agency (EPA) sets standards for drinking water quality and implements various technical and financial programs to ensure drinking water safety. Alaska has primacy on regulating public drinking water systems, with many references to federal regulations. Regulations also contain references to drinking water protection areas that have been mapped for many public drinking water systems. Along the transportation corridor, the region surrounding Iliamna Lake and the adjacent communities are in ADEC drinking water protection areas. There are currently no designated drinking water protection areas at the mine site (ADEC 2020a).

There are currently no drinking water wells at the mine site (ADNR 2018a). During exploration and monitoring activities, personnel typically stay in Iliamna and use local water supplies in that community (described below). With project development, groundwater wells would be installed on the northern side of the mine site to supply potable water. Groundwater testing at that location has shown that minimal treatment would be required (filtration, chlorination, and pH adjustment) to develop a potable water source (PLP 2020d).

3.18.1.4 Substrate/Sediment Quality

This section describes baseline information on waterbody substrates at the mine site. Baseline information on wetland substrate is provided in Section 3.22, Wetlands and Other Waters/Special Aquatic Sites, and Section 3.14, Soils. Baseline physical and chemical data on substrate/ sediment from the major drainages and other waterbodies at the mine site were collected between 2004 and 2008 (Knight Piésold 2011a; HDR 2011a; R2 et al. 2011a; SLR et al. 2011a; Three Parameters Plus and HDR 2011). Sample locations are shown on Figure 3.18-3. The National Uranium Resource Evaluation (NURE) program also collected a variety of substrate samples across the region in 1977 (Grossman 1998). NURE data include basic physical substrate descriptions and thorough chemical analyses, as well as reporting of potential contaminant sources, and are included below. NURE collected and analyzed data for eleven elements, including arsenic, cerium, copper, hafnium, iron, lead, sodium, thorium, titanium, uranium, and zinc (Grossman 1998).



Sources: PLP 2019-RFI153;
SLR et al. 2011a

US Army Corps of Engineers

1 0 1 2
Miles

Sediment Quality Sample
Major Drainage Boundary

Action Alternatives

Natural Gas Pipelines
Alternative 1a
Alternative 1

Other Features

River/Stream
Lake/Pond
100' Contour (Existing)

SEDIMENT QUALITY SAMPLE LOCATIONS, MINE SITE AREA

PEBBLE PROJECT EIS

FIGURE 3.18-3

Physical Characteristics—Waterbody substrate data coverage in the mine site includes the SFK, NFK, and UTC drainages. Streambed sediment from these drainages is dominated by medium to coarse gravels to small cobbles, with boulders present in stretches of rapids. In areas of low water velocity and pools, sands and silts are more common, and organic sediments are present in some areas (Knight Piésold 2011a; R2 et al. 2011a). The NURE data collected from the region include basic physical substrate descriptions and thorough chemical analyses, as well as reporting evidence for potential local contaminant sources. Twelve samples of pond substrate collected by NURE within approximately 20 miles of the mine site were all reported as mud/fine sediment (Grossman 1998). Limited data from the shores of Frying Pan Lake show a sand, silt, and gravel substrate (R2 et al. 2011a).

Chemical Quality—Between 2004 and 2007, a total of 198 samples of sediment from lakes, ponds, seeps, and major and minor drainages in the analysis area were analyzed for their content of naturally occurring trace elements, anions, cations, and organics (SLR et al. 2011a). A summary of the data is provided in Table K3.18-19. Samples collected from wetland substrates are included in the summary of soil chemical quality in Appendix K3.14, Soils, Table K3.14-2 and Table K3.14-3.

Of the 26 trace elements for which samples were analyzed, all were present above analytical detection limits in at least some of the samples, with aluminum, calcium, iron, and magnesium present at substantially higher concentrations than the other elements. Mercury content of sediment samples from the mine site was the lowest level detected, at a mean concentration of 0.040 milligram per kilogram (mg/kg). Comparing sediment from the major drainages, copper was the only element showing significant variation, likely due to the difference in rock composition across drainages. Copper concentrations were particularly high in SFK sediment, likely due to copper-rich bedrock at the headwaters. In comparison to federal National Oceanic and Atmospheric Administration (NOAA) sediment quality guidelines (SQGs) (see Table K3.18-1), the highest detected concentrations of four metals (arsenic, chromium, copper, and nickel) exceeded concentrations that may have an adverse effect on benthic organisms (both the threshold effects level [TEL] and higher probable effects level [PEL)]). These samples were from sediment in the SFK drainage (for arsenic and copper) and UTC drainage (for chromium and nickel). The mean concentration of arsenic exceeded the TEL across the study area.

Sediment from ponds and minor drainages in the mine site area showed higher concentrations of anions and cations such as sulfate, ammonia, and sodium than did other waterbodies. Total cyanide concentrations were the lowest of the analyzed anions on average, with a mean concentration of 0.39 mg/kg (SLR et al. 2011a). Of the 12 pond sediment samples analyzed by the NURE within 20 miles of the mine site area, none showed evidence of contamination (Grossman 1998).

Analyses of several organic compounds (gasoline-range organics [GRO], diesel-range organics [DRO], residual-range organics [RRO], volatile organic compounds [VOCs], semi-volatile organic compounds [SVOCs], and polynuclear aromatic hydrocarbons [PAHs]) were performed on one mine site pond sample to identify the potential presence of naturally occurring hydrocarbons. Of the compounds analyzed, DRO, RRO, and 12 of 18 PAHs were detected. Because of the remote, undeveloped nature of the area, these compounds are likely present due to the biogenic breakdown of aquatic plants, historic wildfires, or volcanic activity (Abdel-Shafy and Mansour 2015). Total organic carbon was detected in all 34 samples tested, with a mean concentration of 6.05 percent.

3.18.2 Transportation Corridor

This section addresses the available water and sediment quality data in the vicinity of transportation corridors under all alternatives. The transportation corridor under all alternatives would cross numerous streams in the Bristol Bay and Cook Inlet watersheds, including crossing Iliamna Lake. The transportation corridor originates in the Nushagak watershed at the mine site and traverses the Kvichak watershed on the northern side of the Alaska Peninsula; both are in the greater Bristol Bay watershed (see Figure 3.16-1). The southern end of the corridor terminates in the Tuxedni-Kamishak bays watershed of the greater Cook Inlet watershed. More detailed descriptions of these watersheds are provided in Section 3.16, Surface Water Hydrology.

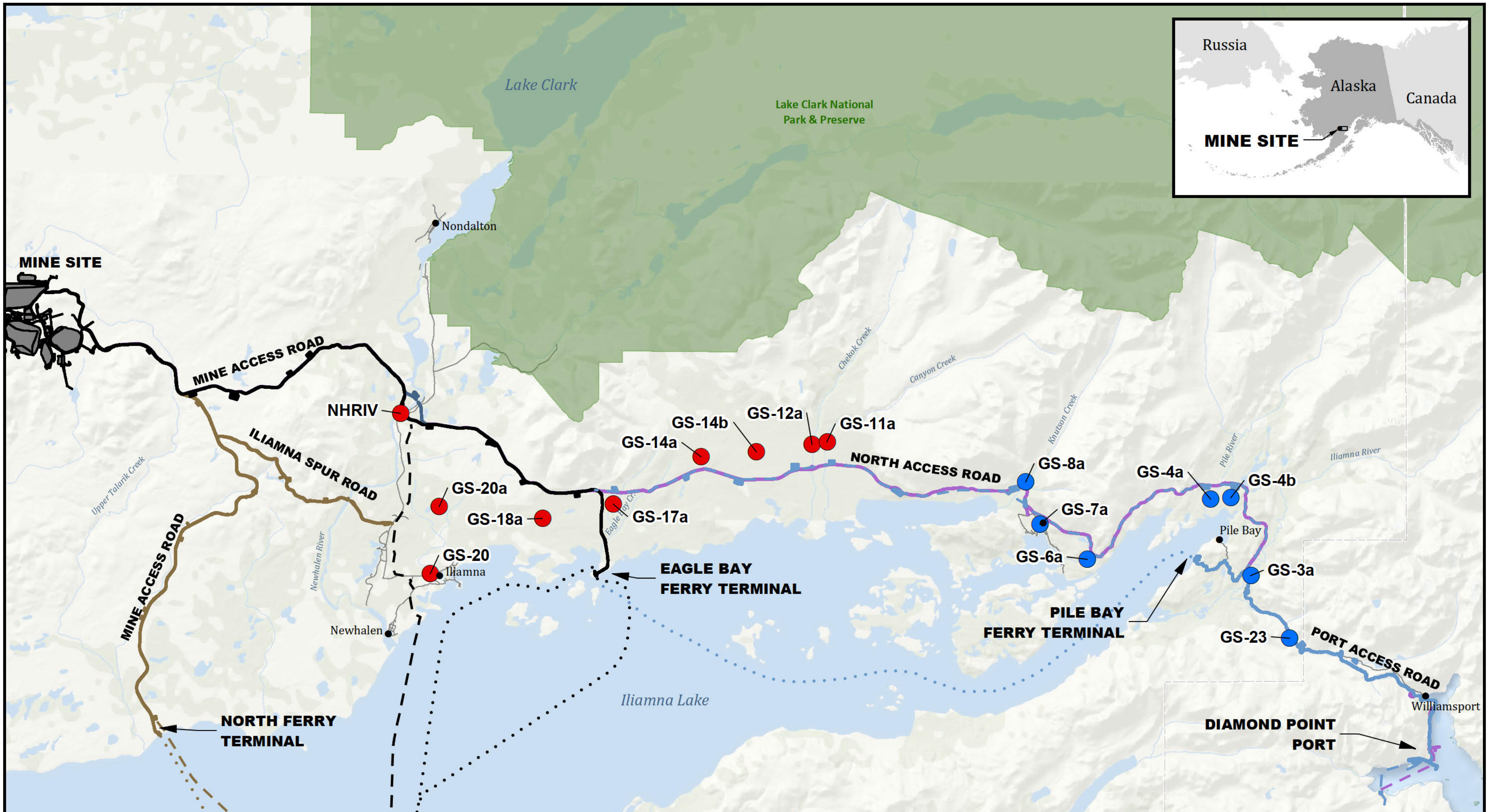
3.18.2.1 Surface Water Quality

Mine Access Road UTC Drainage—Surface water quality data described above for the UTC drainage at the mine site are pertinent to mine access road segments for all alternatives. All alternatives traverse the upper UTC watershed, while the Alternative 1 mine access road also extends through the lower UTC drainage (Figure 3.18-1). Stream data for UTC are summarized in Table K3.18-9, and spatial trends are presented in Table K3.18-16. Although exceedances were measured in some samples, mean concentrations of all measured constituents for the UTC were below the most stringent water quality standards. Additionally, field studies in 2018 included turbidity measurements at 19 stream crossing sites along the mine access road and the Iliamna spur road specific to Alternative 1. These measurements yielded results below the minimum detection level for the instrument used (65-centimeter turbidity tube; 7 Nephelometric Turbidity Units [NTU] detection level) (PLP 2018-RFI 036).

Mine Access Road and North Access Road—Three surface water sampling stations are on the mine access road segment from the mine site to the intersection with the access road to the Eagle Bay ferry terminal. Sixteen surface water sampling stations were established and sampled by Schlumberger et al. (2011a) along the north access road extending east from the Newhalen River (Figure 3.18-4) to Williamsport (Alternative 2 and Alternative 3). Approximately 12 samples were collected at each station over a 2-year period in 2004 and 2005. Table K3.18-11 and Table K3.18-12 provide a summary of the surface water quality data for the western and eastern parts of the north access road, respectively. Data are described below for both the Newhalen River and collectively for all stations along the north access road.

The surface water was characterized by low levels of TDS (2 to 126 mg/L for all stations, 18 to 45 mg/L for Newhalen River); mostly near-neutral pH (4.6 to 8.8 for all stations, 6 to 7.8 for Newhalen River); and high DO concentrations (9 to 19 mg/L for all stations, 9 to 17 mg/L for Newhalen River). Additionally, TSS for all stations ranged from 0.2 to 51.6 mg/L, and 0.5 to 9.1 mg/L for Newhalen River. During months when surface water samples were collected, temperatures ranged from 0.1 to 23ºC for all stations, and 1 to 16ºC at the Newhalen River station. The full annual range of water temperatures could not be characterized because samples were not collected during some winter months (November, December, or January).

The cation composition of the water samples was dominated by calcium, and was consistent between sampling events. The anion composition was typically dominated by bicarbonate, but varied over time. Concentrations of nutrients were low; specifically, most ammonia and phosphorous concentrations were below detection limits. Total nitrogen (nitrate+nitrite) averaged 1 mg/L for all stations and 0.37 mg/L for the Newhalen River. Collectively for all stations, concentrations of the trace elements aluminum, copper, lead, and zinc were above the most stringent ADEC maximum criteria in a few cases. Only aluminum was above the most stringent criterion in about half of the Newhalen River samples.



Sources: PLP 2020-RFI168;
PLP 2019-RFI153; Schlumberger et al. 2011a

US Army Corps of Engineers

3 0 3 6
Miles

Surface Water Quality Sample Location - West
Surface Water Quality Sample Location - East

Action Alternatives
Ferry Routes
Natural Gas Pipelines
Alternative 1a
Alternative 1
Alternative 2
Alternative 2 Newhalen River North Crossing Variant
Alternative 3

Other Features
Local Roads
Borough Boundary
National Park

SURFACE WATER QUALITY SAMPLE LOCATIONS - NORTH ACCESS ROUTE

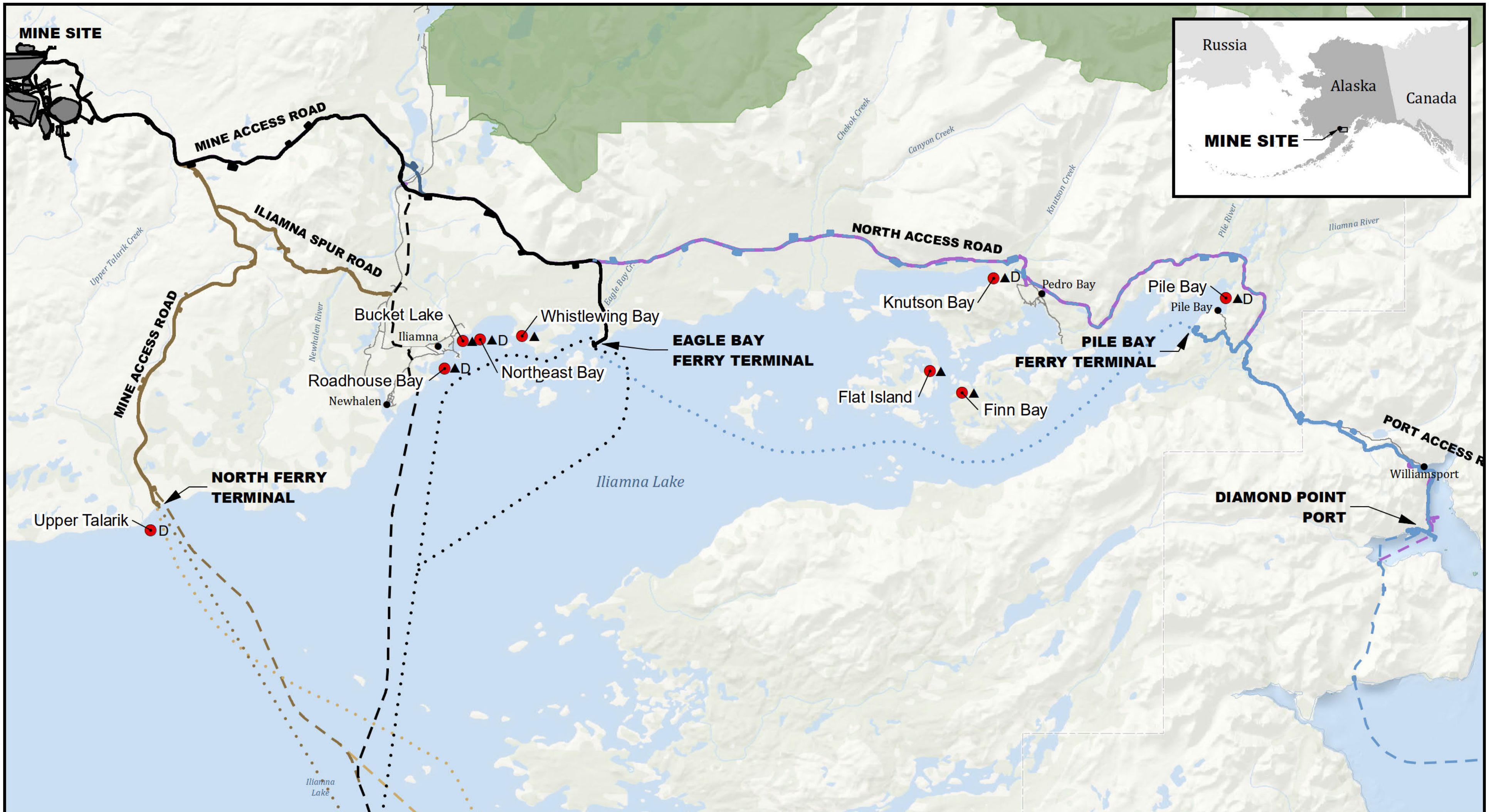
Port Access Road—Water quality data are limited along the port access road from the south ferry terminal to Amakdedori (Alternative 1a and Alternative 1). Field studies in 2018 recorded turbidity measurements at 97 stream crossings along the port access road at levels below the instrument detection level (7 to 11 NTU) for all but two stream crossings, at which turbidity levels of 24 and 13 were recorded. Turbidity measurements at the Gibraltar River crossing were also below the instrument detection level (PLP 2018-RFI 036). No additional water quality data were collected for the Gibraltar River. While turbidity measurements have not been collected along the road associated with the Kokhanok East ferry terminal variant, baseline conditions at stream crossings in this area are expected to be similar to those collected along the main port access road due to the similar nature of the terrain.

Iliamna Lake—A total of 176 surface water samples was collected at nine stations in northeastern Iliamna Lake (May to October) between 2005 and 2007 (HDR 2011a). Stations near Alternative 1 include one near the mouth of UTC, and four near Iliamna village; four additional sites were at the eastern end of the lake. Samples were collected at multiple depths at five of the nine locations (Figure 3.18-5). Ambient water measurements included DO, temperature, specific conductance, oxidation reduction potential, pH, turbidity, and water clarity. Table K3.18-13 provides a summary of the lake water quality data. Samples were collected and analyzed at various locations in four different regions: UTC, Iliamna Village area, Pedro Bay area, and at Pile Bay. The UTC drainage and Iliamna Village area sample locations represent water quality information for Alternative 1a; and the Pedro Bay area and Pile Bay area lend relevant water quality insight for transportation alternatives using mine access along the northeastern side of Iliamna Lake.

The sample data for all sites suggest that Iliamna Lake has water quality conditions similar to the natural conditions of other regional lakes. Aluminum, copper, iron, lead, manganese, and alkalinity were detected at concentrations that were outside the most stringent ADEC water quality criteria; however, mean concentrations did not exceed water quality criteria. Cation and anion dominance was generally characteristic for temperate lakes. Concentrations of major ions did not vary with depth, suggesting that the water at the sampling sites was well mixed. The concentrations of several major ions and TDS were lower earlier in the summer, peaked in September, and declined again in October. These temporary increases are likely associated with the influence of inflow from streams and precipitation.

Regional variations in constituent concentrations were observed for some trace elements, including aluminum, cobalt, copper, iron, lead, and manganese. In particular, significant variation was observed in the mean concentration of aluminum. Mean concentrations of total aluminum varied greatly between locations; mean concentrations at Pile Bay were more than 10 times those of the UTC area. Chromium, cobalt, copper, iron, lead, and manganese also showed some notable variation (about 50 percent change) in mean concentrations. Samples collected at UTC consistently yielded lower concentrations than other locations for these trace metals.

HDR noted that concentrations of nutrients and major ions found during the 2005 to 2007 study were similar to concentrations from a study conducted at Iliamna Lake nearly 40 years before. The single exception was sodium, which was present at nearly twice the concentration found in the earlier study. However, only a few ions (aluminum, copper, iron, lead, manganese, and alkalinity) had concentrations outside water quality standards established by ADEC for freshwater. The investigators attributed the latter to geological influences, and noted their consistency with previous studies conducted at Iliamna Lake and other area watersheds (HDR 2011a).



Sources: PLP 2020-RFI168;
PLP 2019-RFI153; HDR 2011a

US Army Corps of Engineers

3 0 3 6

Miles

Water Sample Locations

- Shallow samples collected 3' below lake surface
- D Deep samples collected at 1/2 total depth + 3' above lake bottom
- ▲ Sediment sample location

Action Alternatives

- Ferry Routes
- Natural Gas Pipelines
- Alternative 1a
- Alternative 1
- Alternative 1 Kokhanok East Ferry Terminal Variant
- Alternative 2
- Alternative 2 Newhalen River North Crossing Variant
- Alternative 3

Other Features

- Local Roads
- Borough Boundary
- National Park

SURFACE WATER AND SEDIMENT SAMPLE LOCATIONS - ILIAMNA LAKE

Field data collected in 2017 added three additional sample locations assessing the surface water quality near the ferry terminals in Iliamna Lake. Samples were taken near the surface and near the bottom of the lake. These data did not yield any exceedances of the most stringent water quality criteria (Table K3.18-1) for total or dissolved metals, or any conventional parameters tested (GeoEngineers 2018a, Table 6a).

Drinking Water Sources—Three communities around Iliamna Lake have community surface water systems as their primary drinking water source, including Nondalton, Kokhanok, and Igiugig (see Figure 3.16-1). Nondalton uses infiltration galleries from Six Mile Lake (which drains into the Newhalen River); Kokhanok draws water from Iliamna Lake; and Igiugig has one active intake in the Kvichak River, just downstream of Iliamna Lake. No State of Alaska data are available on drinking water sources for Pile Bay and Williamsport (ADEC 2018; ADNR 2018a).

Past water system violations in these communities reported by ADEC (between 1995 and 2018) are mostly monitoring violations that represent failure to collect a sample. Drinking water standard exceedances are rare, but have included arsenic, coliform, copper iron, lead, and manganese (ADEC 2018).

3.18.2.2 Groundwater Quality

Mine Access and Port Access Roads—Limited groundwater quality data are available along the transportation corridor under all alternatives. Hydrogeological characterization and a description of aquifers beneath the transportation corridor are expanded in Section 3.17, Groundwater Hydrology. The transportation corridor under all alternatives can be characterized as similar to that of the mine site, port site(s), and drinking water wells. Along the north access road in the Nushagak and Kvichak watersheds, the groundwater quality of the transportation corridor is likely similar to that of the mine site along the western portion, and characterized more similarly to the drinking water wells sampled at Newhalen, Nondalton, and Iliamna. Trend analysis of the mine site groundwater system suggests that TDS concentrations decrease with distance from the mine site. The port access road (under Alternative 1a and Alternative 1) would traverse flat ground and low hills, much of which are bare rock covered with a thin layer of soil (AECOM 2018h). There are few known potentially groundwater-bearing surficial deposits along the port access road, with few intermittent glaciofluvial and alluvial surficial deposits (Detterman and Reed 1973). This terrain suggests that shallow groundwater occurrences along this route would be limited. Groundwater quality beneath the port access road is likely similar to that of the port site.

North Access Road—The north access road traverses a series of shallow intermittent surficial deposits, including glacial, glaciofluvial, and alluvial deposits, making groundwater quality potentially more variable along this route (Detterman and Reed 1973). The north access road would cross a variety surficial deposits, all of which have the potential to be groundwater-bearing. These are intermittent in the eastern part of the route and thicker in the western part of the road (Detterman and Reed 1973; Schlumberger et al. 2011a). Groundwater quality and characteristics can be influenced by these surficial deposits and bedrock geology, which is complex throughout the Cook Inlet basin (Brabets et al. 1999). A single groundwater quality sample was collected in Pedro Bay near the northern access route, and was similar in quality to wells sampled at Newhalen, Nondalton, and Iliamna (Schlumberger et al. 2011a).

3.18.2.3 Drinking Water Wells

The village of Newhalen uses both community and private groundwater wells as drinking water sources, while Iliamna and Pedro Bay rely on private groundwater wells. Drinking water wells were sampled at four locations (Newhalen, Nondalton, Iliamna, and Pedro Bay) in 2004 and 2005 to assess regional water quality across the transportation corridor (Schlumberger et al. 2011a).

These wells were similar in quality, with exceedances of drinking water quality standards for total arsenic in Newhalen, Nondalton, and Pedro Bay; and pH exceedances in Newhalen and Pedro Bay. Newhalen has had numerous monitoring violations from failure to collect a sample since 1995, but rare exceedance violations have only been registered for coliform (ADEC 2018a).

3.18.2.4 Substrate/Sediment Quality

Physical Characteristics—Stream substrates intersected by the transportation corridor under all alternatives include a wide range of fine to coarse sediments (Grossman 1998). Stream sediments at the northern end of the road corridor are dominated by sand and silt, with some stretches high in gravel and cobbles, while other stretches are rich in organic matter (PLP 2018-RFI 036). Limited substrate data along the Iliamna spur road (Alternative 1) show that some stream crossings are dominated by gravel and cobbles, while others are high in fine-grained sand, silt, and organic matter. Along the mine access road south of the intersection with the Iliamna spur road, substrates are dominantly silt, sand, and gravel (PLP 2018-RFI 036). No substrate data are available for streams along the southern portion of the mine access road (Alternative 1). A small number of nearshore and deeper water sediment samples from Iliamna Lake were collected in 2005 and 2006 (Figure 3.18-5). Substrate offshore of the north ferry terminal near the mouth of UTC was described as consisting of small gravel. Lake sediment analyzed near Iliamna Village was described as fine-grained material (HDR 2011a). Sediment samples collected near the ferry terminals in Iliamna Lake in 2017 consist primarily of underdeveloped sand-gravel beaches with intermittent cobble, larger rocks, and occasional outcrops of bedrock (GeoEngineers 2018a).

Stream substrates along the port access road show similar diversity to those north of Iliamna Lake. Sand and silt are the dominant sediment size, with a high percentage of organic matter present as well. Sampled streams have a higher percentage of boulders and less gravel south of Iliamna Lake. Sediment at the location of the Gibraltar River bridge is dominated by gravel and cobble substrate. Sediments in drainages with crossings by the other four bridges along the port access road tend to be more coarse-grained, with a higher percentage of cobbles and boulders (PLP 2018-RFI 036). Samples of substrate from four ponds within approximately 5 miles of the southern access road were all recorded as mud/fine sediment (Grossman 1998).

Chemical Quality—Table K3.18-20 provides a summary of Iliamna Lake sediment quality data collected in 2005 and 2006. Sediment quality measurements for Iliamna Lake were examined at the Iliamna Village area (four sample locations), Pedro Bay area (three sample locations), and at Pile Bay (one sample location). Minor variations in sediment content occur between the three areas; however, mean constituent concentrations only exceeded TELs for cadmium in the Iliamna Village area, and for copper at the Pile Bay location. In these instances, concentrations did not reach the probable effects level. Sediment samples collected from two locations near Iliamna Village (Figure 3.18-5) were analyzed for trace elements and other constituents (HDR 2011a). Sediment data showed levels for aluminum, copper, iron, lead, and manganese that exceed ADEC freshwater sediment criteria (same as SQGs). This is likely due to the highly mineralized nature of the local geology, and is similar to chemistry in other area lakes.

Of 12 pond substrate samples analyzed by NURE within approximately 20 miles of the north access road, none showed evidence of contamination from an outside source (Grossman 1998). Of four pond substrate samples analyzed by NURE within approximately 5 miles of the port access road, none showed any evidence of contamination from an outside source (Grossman 1998).

3.18.3 Marine Ports

3.18.3.1 Surface Water Quality

The following discussion of marine water quality presents regional information, as well as data collected in northern Kamishak Bay (2004 to 2012) and offshore of the Amakdedori port site (2018) that are pertinent to Alternative 1a and Alternative 1. Additional details of marine water quality in the Iliamna/Iniskin estuary north of Kamishak Bay that are pertinent to the Diamond Point port (Alternative 2 and Alternative 3) are provided in Appendix K3.18.

Suspended Particulates/Turbidity—Cook Inlet basin is an expansive watershed surrounding the 180-mile-long Cook Inlet waterbody. Covering more than 38,000 square miles of southern Alaska, it receives water from six major watersheds and many smaller ones. More than 10 percent of the basin is covered by glaciers, and suspended sediment loading in glacier-fed rivers without lakes is significant, leading to generally high suspended sediment load in some portions of Cook Inlet (PLP 2018d), particularly in the upper inlet areas.

Hart Crowser (2015a) provides physical and chemical data from the Ursus Cove area at the northern end of Kamishak Bay (about 17 miles northeast of Amakdedori), which are likely similar to the Amakdedori port site because of its exposure to lower Cook Inlet oceanographic conditions. Turbidity in the sampled areas at the northern end of Kamishak Bay ranged from near 0 to 13 NTU, probably reflective of varying exposures to wave activity. Turbidity was described as generally moderate, except near the shoreline during windy periods, and did not exhibit any obvious trends that would indicate point-source inputs (Hart Crowser 2015a). TSS was 5 mg/L at both surface and bottom, indicating a well-mixed and relatively clear water column.

Overall, turbidity in Iliamna Bay tended to be greater than in Ursus Cove and Iniskin Bay. Field turbidity measurements in Iliamna Bay indicate measured mean turbidity of approximately 21 NTU (Hart Crowser 2015a). Hart Crowser (2015a) notes that higher turbidity levels in Iliamna Bay may be the result of reflected wave energy and proximity to mudflats, although sediment characteristics in Iliamna Bay are similar to those of Ursus Cove. Turbidity in Iliamna Bay north of Diamond Point is also impacted annually by maintenance dredging at Williamsport, which temporarily increases turbidity in northern Iliamna Bay. Maintenance dredging typically occurs in May or June, and removes approximately 2,250 cubic yards of material (USACE 2011b).

The amount of suspended solids and accompanying turbidity in waters adjacent to the Amakdedori port site would be a function of seabed composition (e.g., silt, mud, sand). Extrapolation of onshore geophysical survey data (Zonge 2017) and NOAA (2015) nautical chart information for the approach to the port site suggest that the seabed in this area consists of sand and gravel with scattered boulders. This suggests that suspended solids are of naturally low concentrations, and that water is relatively clear (i.e., low turbidity). Field studies conducted in 2018 at four offshore locations near the Amakdedori port site (two near-bottom and two near-surface samples) measured no exceedances of the ELG for TSS with an average of 15.3 mg/L (GeoEngineers 2018a, Table 5). However, under energetic wave conditions, any loose sediment on the seabed would be stirred upward into the water column, thereby temporarily increasing suspended solids and turbidity.

Salinity Gradient and Temperature—The Amakdedori port site is on the open coast of Kamishak Bay. Therefore, water properties such as salinity and temperature can be expected to be similar to those of lower Cook Inlet (Muench and Schumacher 1980). However, some freshening of surface waters in the immediate vicinity of Amakdedori Creek might occur; while under southerly winds, greater freshening could occur as a result of flows from sources to the south, such as McNeil and Kamishak rivers. The extent of any freshening is dependent on flows from those sources and the persistence of southerly winds. The freshening of surface waters would be manifest as a thin, low-salinity lens overlying saltier water, which would be mixed quickly into the water column by any wave action produced by brisk winds.

Hart Crowser (2015a) temperature and salinity data from the Ursus Cove area are likely to be similar to the Amakdedori port site, although they may be influenced by freshening from upland sources through Ursus Lagoon. For the 2012 sampling period (August), mean water temperatures ranged from 12.9 to 14°C, while mean salinities ranged from 22.8 to 25.7 parts per thousand. Hart Crowser (2015a) reported similar observations in Iliamna Bay. Field measurements indicate that mean surface water temperatures in the bay ranged from 6.4 to 12.1°C, with an average of approximately 9.4°C throughout the bay. Salinity in Iliamna Bay was similar to that of Ursus Cove and the Amakdedori port site, ranging from 16.1 to 28.7 parts per thousand. The small range in data for both temperature and salinity suggests a fairly homogenous water column. Temperature exhibited seasonal warming up to mid-summer, and then subsequent cooling, but was also a function of water depth, indicating the role of insolation as a factor in temperature trends. Salinity decreased from spring to late summer, reflecting the influence of upland sources on coastal waters, and then increased in autumn months.

Organics and Inorganics—The area surrounding Cook Inlet north and east of the port site is a relatively populated and industrialized region of Alaska. Therefore, its waters are influenced to some degree by urban (and a small amount of agricultural) runoff, oil and gas activities (e.g., accidental spills, discharges of drilling muds and cuttings, production waters, and deck drainage), effluent from municipal wastewater treatment facilities, oil and other chemical spills, offal from seafood processing, and other regulated discharges. Waters free from contaminants, however, are considered a principal component of the Cook Inlet beluga whale critical habitat in the Amakdedori port area. Therefore, the comparatively low levels of contaminants documented in Cook Inlet beluga whales, as well as in chemical analyses of water and sediment in the area, suggest that contaminant concentrations in lower Cook Inlet are low (NMFS 2016a).

Hydrocarbon concentrations sampled in 2004 at the northern end of Kamishak Bay, as well as metal and trace element concentrations collected in 2008, showed little to no effect from anthropogenic sources. The majority of organic constituents tested were not detected (Hart Crowser 2015a: Table 34-7). Inorganics analyzed in both surface water and bottom water at a depth of about 50 feet in northern Kamishak Bay (Hart Crowser 2015a: Table 34-8, Station MRC20) showed that none exceeded Alaska water quality standards or National Recommended Water Quality Criteria (EPA 2018d). In samples collected offshore of the Amakdedori port site, exceedances of marine water screening levels were measured in boron for both total and dissolved metal concentrations at all locations. Additionally, total iron concentrations exceeded the marine screening level for all sample locations (GeoEngineers 2018a: Table 5).

3.18.3.2 Groundwater Quality

Aquifer systems found in small drainages around the Cook Inlet region, such as those in the Amakdedori and Diamond Point port areas, include groundwater occurrences in saturated fractures in bedrock that provide water to streams near the port areas during winter (Glass 2001). Aquifers are primarily situated in glacial and fluvial deposits overlying sedimentary and low-grade metamorphic bedrock. Glacial deposit aquifers have been described as irregular in distribution and highly variable in composition and flow (Brabets et al.1999).

The thickness of surficial deposits in the Amakdedori port area are believed to range from about 50 to 100 feet thick in the port area, based on geophysical survey results (Zonge 2017). Potential groundwater-bearing surficial deposits in the Diamond Point area would be limited to alluvium and alluvial fan deposits in the small drainage west of Diamond Point, and morainal deposits in uplands west of the terminal (Detterman and Reed 1973). There are no existing drinking water wells in either port area. Potable water supplies for seasonal work at the Diamond Point quarry come from temporary mobile sources (ADNR 2014a).

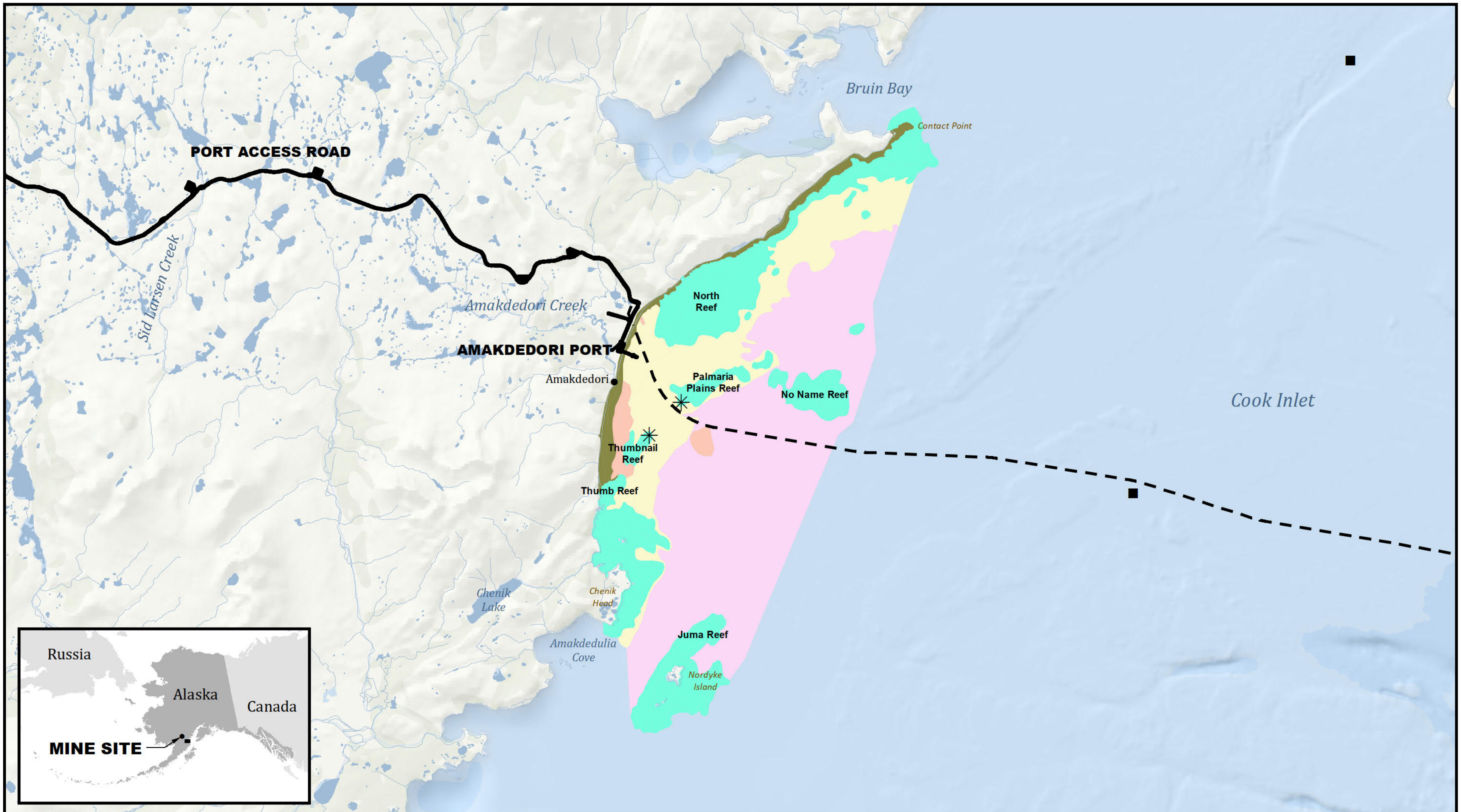
3.18.3.3 Substrate/Sediment Quality

Physical Characteristics—Studies in upper and lower Cook Inlet provide a general characterization of seafloor substrate and sediment depositional processes in the region. Lower Cook Inlet is a tidal embayment with a substrate of abundant glacial sediments, predominantly cobbles, pebbles, and sand, with minor amounts of silt and clay (Sharma and Burrell 1970). Large ice-rafted boulders are also present in some areas (Thurston and Choromanski 1994). Over 40 million tons of sediment are discharged per year into the inlet by surrounding major drainages (Rember and Trefry 2005). Sediment transport in some areas of upper Cook Inlet has been shown to be exceptionally high, with 10,000 to over 100,000 cubic yards of sediment moving in and out of the Port of Anchorage area in a matter of days or weeks (USACE 2013). A combination of shallow water, high tidal fluctuations, and strong currents constantly mobilize seafloor sediments in the inlet, keeping sediments in suspension, resulting in highly turbid water, and inhibiting deposition of fine-grained sediments (Rember and Trefry 2005). Fine sediments introduced by major rivers feeding into upper Cook Inlet are carried in suspension, and have been shown to be deposited as far as 150 miles south in lower Cook Inlet (ADL 2001). Analysis by Atlas et al. (1983) determined that Kamishak Bay is a natural depositional area for fine sediments and hydrocarbons. Kamishak Bay is primarily composed of unconsolidated sediment with fine silt/clay being found intertidally and sub-tidally, with rocky substrates occurring along much of the shoreline, and extending into the intertidal zone (GeoEngineers 2018c). At the Amakdedori port site, studies suggest that substrates are a mixture of sands and fine materials, gravel, and rocky reefs. The areas accounting for these substrate types are relatively equally dispersed, with nearshore areas primarily typified by gravels and reef features, and outer areas more typified by sands and fines (GeoEngineers 2018c, Figure 4).

The shoreline at Amakdedori is a wave-dominated coastal berm largely composed of weathered cobbles, boulders, and exposed bedrock rising from the intertidal zone (GeoEngineers 2018a, c). Amakdedori Creek alluvial fan-delta deposits extend about 1,000 feet offshore into Kamishak Bay (PLP 2018-RFI 039). Seafloor sediment at and around the Amakdedori port location is primarily composed of subtidal gravel and beach complex (GeoEngineers 2018a, Figure 2). Bathymetry in Kamishak Bay around the Amakdedori port location was investigated through a multi-beam survey in 2017, which indicated that the seafloor is relatively smooth, with a gentle slope (60 feet over 5.6 miles). Results from three boreholes indicate that sub-bottom sediment consists primarily of fine silty sand with occasional course gravel and shell fragments, and a fines content ranging from 14 to 19 percent. Sediment samples from the estuarine environments of Iliamna and Iniskin bays, about 30 miles northeast of the port site, revealed substrates of fine sediment (SLR et al. 2011a).

Waterbody substrate data from the onshore environment at the Amakdedori port site are limited. Sediment from two ponds, one about 0.5 mile north and the other approximately 3 miles south, was described as mud/fine sediment (Grossman 1998).

Figure 3.18-6 through Figure 3.18-8 depict spatial characterization of marine substrates for Amakdedori Bay, Ursus Cove, and Iliamna Bay following 2018 field investigations (GeoEngineers 2018c). Substrate along the Ursus Cove beach is characterized primarily by beach complex with intermittent rock and sand/fine substrates (GeoEngineers 2018c). Iliamna Bay is composed of mixed gravel at the mouth of the bay, and transitions to sand and fine sediments, and mixed fine sediments further inland. The shoreline of Iliamna Bay is largely beach complex with intermittent reefs, transitioning to mixed fine sediments further inland (GeoEngineers 2018c).



Sources: PLP 2019-RFI153; GeoEngineers 2018c

US Army Corps of Engineers®

2 0 2 4

Miles

Habitat Types

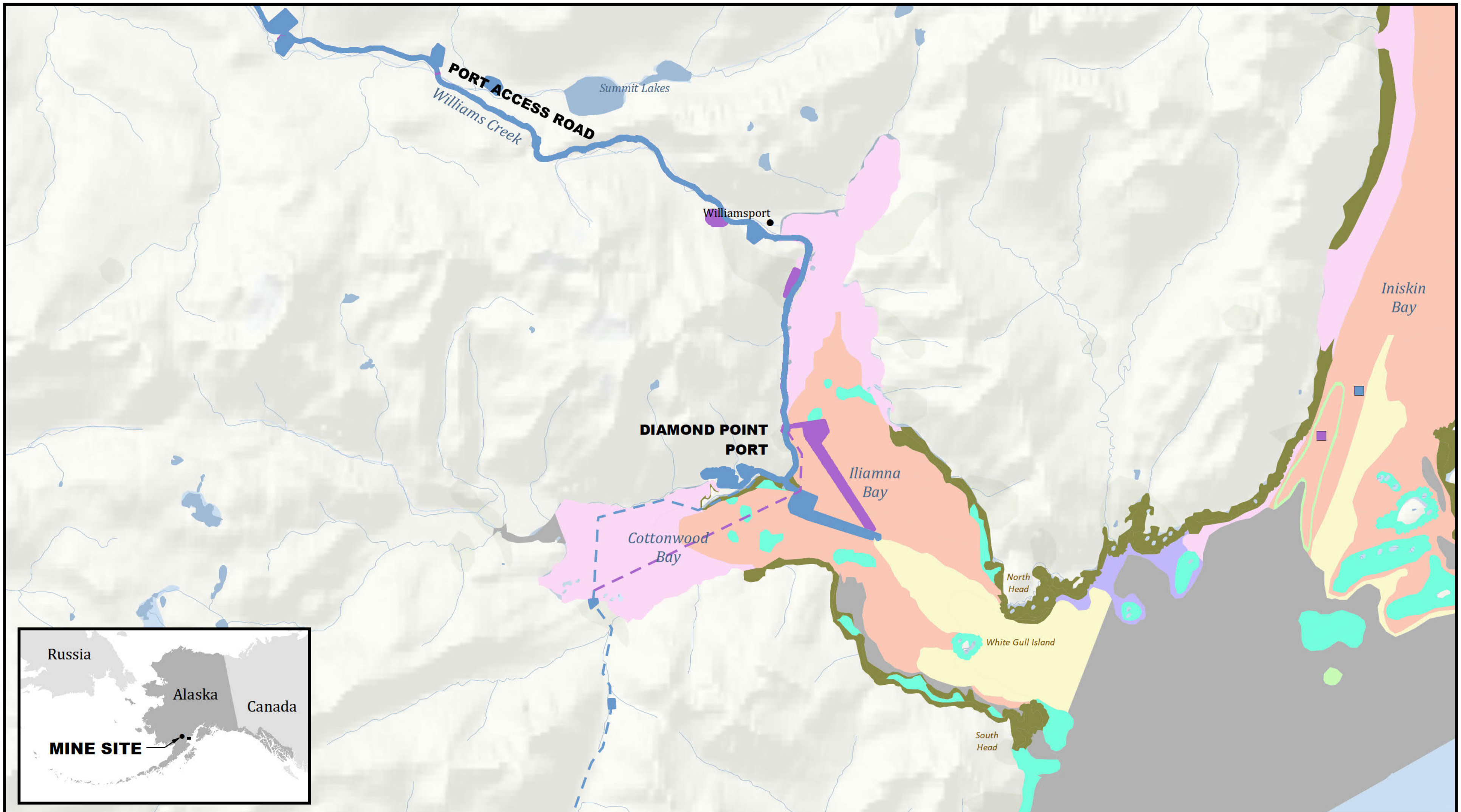
- Beach Complex
- Mixed Fine
- Mixed Gravel
- Reef
- Sand/Fine

Alternative 1a

- Lightering Locations
- Lighted Navigation Buoys
- Natural Gas Pipeline
- Transportation Corridor/Port

MARINE SUBSTRATE CHARACTERIZATION - AMAKDEDORI

PEBBLE PROJECT EIS **FIGURE 3.18-6**



Sources: PLP 2020-RFI168; PLP 2019-RFI153; GeoEngineers 2018c

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0.5 0 0.5 1
Miles

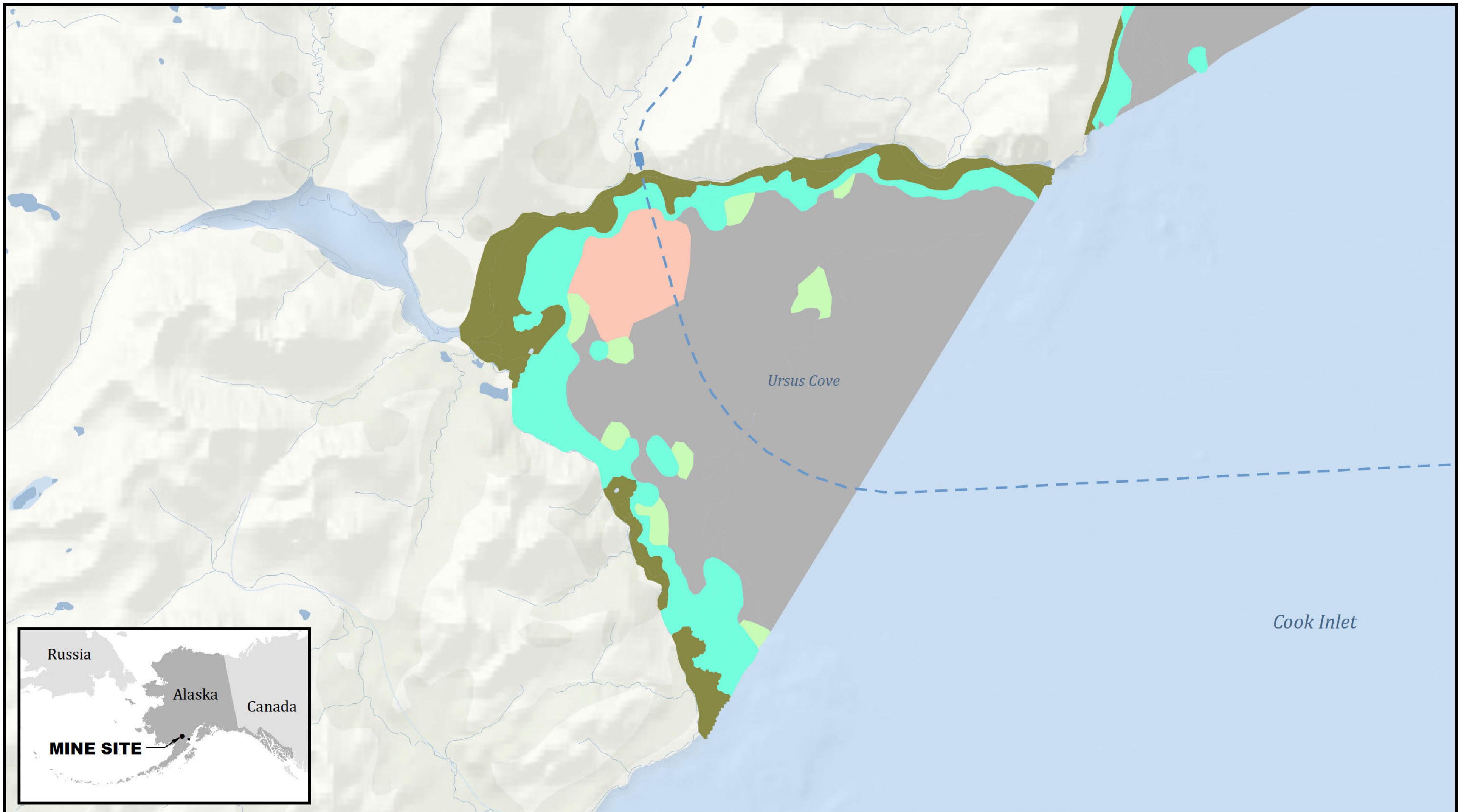
Habitat Types
- Beach Complex
- Hard
- Mixed Fine
- Mixed Gravel
- Reef
- Rocky
- Sand/Fine
- Unknown

Action Alternatives
- Lightering Locations
- Natural Gas Pipelines
- Alternative 2
- Alternative 3

MARINE SUBSTRATE CHARACTERIZATION - ILIAMNA BAY

PEBBLE PROJECT EIS

FIGURE 3.18-7



Sources: PLP 2019-RFI153;
GeoEngineers 2018c

US Army Corps of Engineers

0.5 0 0.5 1
Miles

Habitat Types

- Beach Complex
- Reef
- Rocky
- Sand/Fine
- Unknown

Alternative 2

- Natural Gas Pipeline

MARINE SUBSTRATE CHARACTERIZATION - URSUS COVE

PEBBLE PROJECT EIS

FIGURE 3.18-8

Chemical Quality—Data on regional sediment chemical quality in Cook Inlet are found in PLP baseline studies and other substrate studies, including the Integrated Cook Inlet Environmental Monitoring and Assessment Program. Limited data from dredging operations and sediment sampling suggest that sediments generally have low concentrations of contaminants (USACE 2013; ADL 2001). Low levels of hydrocarbons have been detected at multiple sites in the inlet, potentially connected with offshore oil development, past oil spills, or natural oil seeps in the region. Glacial sediments, which are continually transported into the inlet by the major drainages, may also bring metals and hydrocarbons from upstream sources into Cook Inlet. Municipal discharges and seafood processing also contribute potential contaminants to Cook Inlet substrate. Extreme tidal fluctuations and strong currents constantly disperse and dilute potential pollutants in the inlet (ADL 2001).

Sampling of offshore sediment has been conducted at two locations near the Amakdedori port site, and in various other locations in lower Cook Inlet. Sediment quality data from the two locations near the Amakdedori port site were analyzed for concentrations of inorganic and organic chemicals. Results indicate that concentrations of metals fell below the TEL for all measured quantities except for manganese and nickel. An exceedance of nickel in marine sediments was detected in one sample collected from subtidal sands/fines, but mean concentrations did not exceed the marine TEL. Manganese concentrations exceeded the marine TEL for both sampled locations in subtidal sands/fines, and yielded a mean concentration of 380 mg/kg, exceeding the marine TEL (GeoEngineers 2018a, Tables 7a and 7b).

Samples of fine sediment were collected from the offshore estuarine environments of Iliamna and Iniskin bays near Diamond Point. Some of the samples showed arsenic, copper, nickel, and zinc levels higher than the threshold of biological effect, and measurable hydrocarbons. There is current development in the Diamond Point area, and minor marine vessel traffic at Williamsport at the head of Iliamna Bay. Estuarine sediments are generally more fine-grained than offshore of Amakdedori, which is more exposed to open water. Fine-grained sediments generally retain chemical pollutants more than coarse-grained sediments, due to higher surface area to volume ratios.

Chemical substrate data from the onshore environment at the Amakdedori port site are limited. Sediment from two ponds, one within 0.5 mile to the north and one about 3 miles south of the port site, were analyzed by NURE and were reported to have no contamination (Grossman 1998).

3.18.4 Natural Gas Pipeline Corridor

3.18.4.1 Surface Water Quality

Surface water quality data for the onshore part of the natural pipeline corridor are summarized above under "Transportation Corridor," (including the area of the pipeline-only segment from Iliamna Lake to the mine access road under Alternative 1a). Additional water quality information for Cook Inlet and Kamishak Bay pertinent to the pipeline is summarized above under "Surface Water Quality, Marine Ports." The pipeline would tie into the existing natural gas supply at a compressor station near Anchor Point. This would result in no additional stream or waterbody crossings on the Kenai Peninsula. The closest stream to the horizontal directional drilling (HDD) part of the corridor is about 200 feet to the north (PLP 2017, Figure G-012).

A description of Cook Inlet bathymetry and oceanographic conditions is provided in Section 3.16, Surface Water Hydrology. The USGS National Water-Quality Assessment (NAWQA) Program described water quality in the Cook Inlet as generally good, and that much of the water originates from melting snow and glaciers, resulting in a relatively low level of contaminants (Glass et al. 2004). Further assessment by Saupe et al. (2005) used approximately 20 sample locations, testing a wide variety of water quality parameters, including trace metals, dissolved oxygen, and nutrient levels. All samples collected met the applicable water quality criteria. No evidence suggested heavy metal pollution in Cook Inlet; however, some evidence of elevated mercury in suspended sediments was found, which is likely the result of a combination of natural and anthropogenic sources (BOEM 2016a).

3.18.4.2 Groundwater Quality

Summary groundwater quality information pertinent to the natural gas pipe corridor is described above in "Transportation Corridor." The only additional sections of pipeline that do not match the road alternatives would be the pipeline-only segment from Iliamna Lake to the mine access road (Alternative 1a); at the eastern end of the pipeline on Kenai Peninsula (all alternatives); and the short section from Ursus Cove to Diamond Point (Alternative 2 and Alternative 3).

As described in Section 3.17, Groundwater Hydrology, groundwater beneath Kenai Peninsula is known to occur in thick glacial and alluvial deposits (Karlstrom 1964; Nelson and Johnson 1981). Seven private groundwater wells are currently located a distance of 600 to 1,600 feet away from the HDD part of the pipeline terminus. Groundwater quality data are not publicly available for private wells (ADNR 2018a).

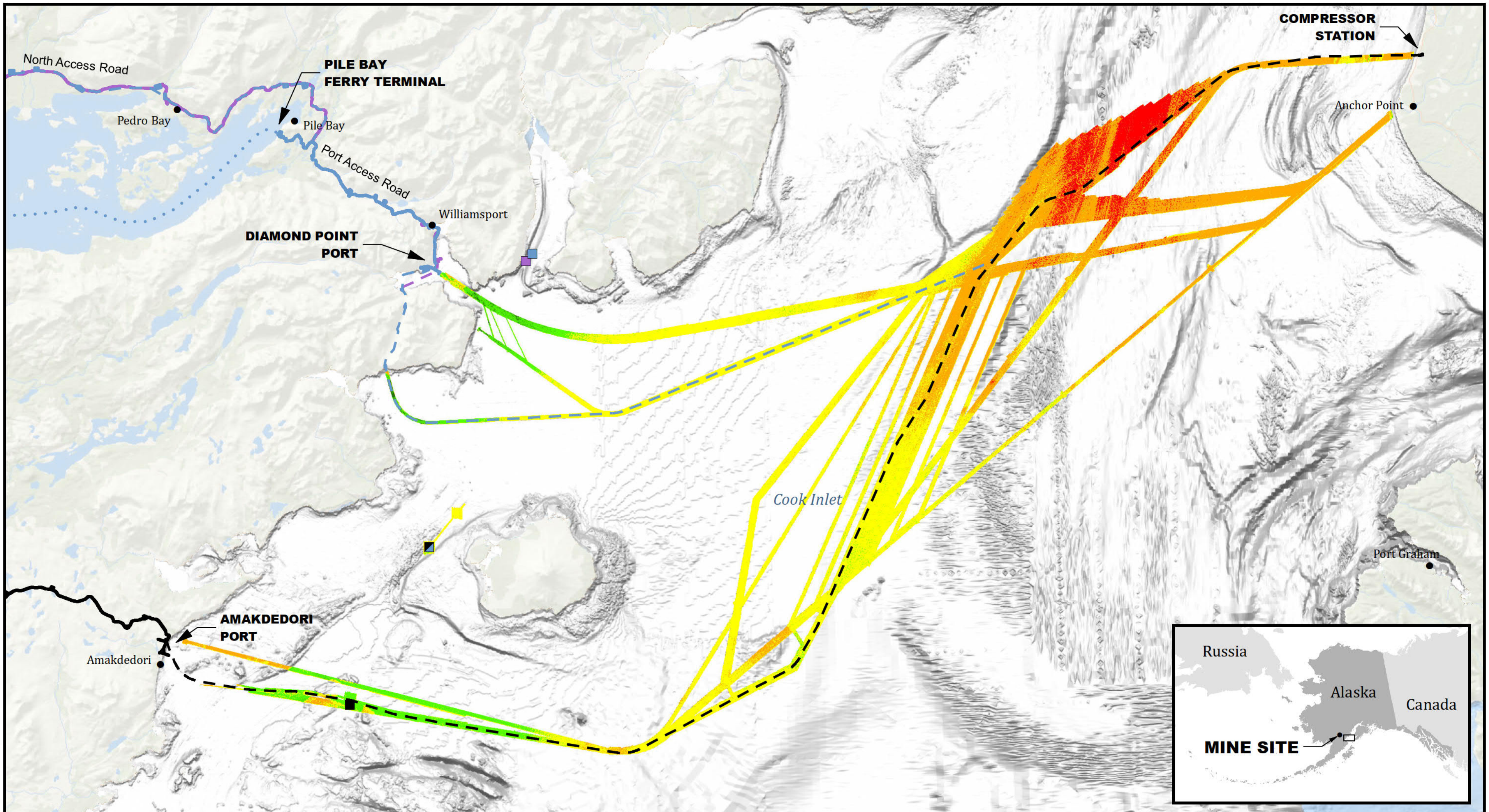
There would be limited shallow groundwater occurrence in a narrow strip of alluvial deposits along the short pipeline corridor between Ursus Cove and Diamond Point (Detterman and Reed 1973). No groundwater quality data have been collected in this area.

3.18.4.3 Substrate/Sediment Quality

Physical Characteristics—Substrate along the Cook Inlet crossing pipeline route ranges from coarse sands and gravel in the northeastern portion of the pipeline route, becoming finer following the pipeline route to the southeast. Along the center of the pipeline crossing of Cook Inlet, substrate transitions to fine to medium sands, and becomes even finer silts and fine sands to the west approaching Kamishak Bay, Ursus Cove, and Iniskin Bay (IntecSea 2019). Figure 3.18-9 depicts physical characteristics and distribution of substrate along potential crossings of Cook Inlet under all alternatives. A description of nearshore Cook Inlet physical substrate characteristics is provided above under "Marine Ports." Field studies indicate that the substrate in the western portion of Kamishak Bay is primarily composed of subtidal gravel with intermittent reef and sand/fine substrate in the region near the port location (GeoEngineers 2018a, Figure 2). Publicly available information regarding the substrate of Cook Inlet in areas further offshore is sparse. Substrate in the vicinity of mooring facilities could include flows from Augustine Volcano, which have been documented to occur approximately every 300 years (Section 3.15, Geohazards and Seismic Conditions).

Water depths in the center of Cook Inlet range from about 50 to over 500 feet (NOAA nautical chart #16660). Numerous oil and natural gas pipelines currently span the bottom of Cook Inlet; however, all current pipelines are in the northern part of the Cook Inlet, and there are none in the vicinity of the project (ADNR 2018d). Pipeline damage has previously been documented from boulders moved on the seafloor by strong tides and currents.

Chemical Quality—Substrates in Cook Inlet are derived primarily from river-borne sediments and have low concentrations of metals and low toxicity (ADL 2001; BOEM 2016a; Saupe et al. 2005). There is no known evidence linking enhanced metals concentrations in bottom sediments to anthropogenic sources (BOEM 2016a). Chemical quality of sediment in the nearshore parts of Kamishak Bay and Iliamna/Iniskin estuary are summarized above under "Marine Ports." Sediment quality data for the offshore part of the pipeline route are limited, as described previously. Sediment sampled from one stream in the Kenai Peninsula area near the eastern end of the pipeline did not show evidence of contamination (Grossman 1998).



Sources: PLP 2020-RFI168; PLP 2019-RFI153; IntecSea 2019

US Army Corps of Engineers®

5 0 5 10

Miles

Preliminary Surficial Sediment Interpretation

- Clays
- Silt
- Fine to Medium Sands
- Medium to Coarse Sands
- Coarse Sands to Gravel or Larger, or Rock
- Other

Action Alternatives

- Lightering Locations
- Ferry Routes
- Natural Gas Pipelines
- Alternative 1a
- Alternative 2
- Alternative 3

SEAFLOOR SEDIMENT DISTRIBUTION - COOK INLET PIPELINE CORRIDORS

PEBBLE PROJECT EIS

FIGURE 3.18-9

3.19 NOISE

Information on applicable noise and vibration concepts and methodologies used in characterizing noise of the affected environment is provided by AECOM (2018c).

"Noise" is typically characterized as unwanted sound. Because the natural existing ambient sound is generally not considered a problem, it is not typically classified as noise. The ambient sound level is a composite of sound from all sources, including the natural background and anthropogenic sources; it is the total sound received by the microphone of a sound level meter. Existing ambient sound levels are often the starting point for analyzing project-associated noise impacts, because such environmental noise analysis typically compares project-associated noise to either existing ambient or natural background sound based on applicable adverse effect or impact assessment criteria.

The Environmental Impact Assessment (EIS) analysis area for this section includes the mine site, transportation corridor, port, and natural gas pipeline corridor for each alternative and variants, and the surrounding area where project-associated noise could have a direct effect on human receptors. A radius of 10 miles from the mine site was used as a screening distance for potential noise impacts; based on preliminary conservative calculations (assuming typical equipment to be used and acoustical propagation rates), noise effects are expected to be not readily detectable beyond 10 miles. Similarly, for all other non-mine site project components (transportation corridor, port, ferry terminal sites, and natural gas pipeline corridor), including all alternatives and variants, a conservative screening distance of 2 miles from the project feature or alignment was used to help locate and identify potential noise-sensitive receptor (NSR) property parcels.

Impacts to other resources from noise are addressed in Section 4.5, Recreation; Section 3.9, Subsistence; Section 3.11, Aesthetics; Section 4.23, Wildlife Values; Section 4.24, Fish Values; and Section 4.25, Threatened and Endangered Species.

The effects of noise on people can include general annoyance, interference with speech communication, sleep disturbance, and in the extreme, hearing impairment. At any location, both the magnitude and frequency of environmental noise may vary considerably over the course of each day and throughout the week and year. This variation is caused not only by various noise source activities, but also by conditions such as changing weather conditions, seasonal vegetative ground cover, presence of ice or flowing water from nearby creeks and rivers, and wind.

Examples of outdoor and indoor noise levels that could be experienced by current residents in or near the EIS analysis area are provided in Table 3.19-1 as context for describing existing conditions. These levels are measured in terms of "A-weighted" decibels (dBA), which are used to quantify sound and its effect on people (EPA 1978), and emphasize frequencies best heard by humans. AECOM 2018c provides explanation of the principles of acoustics and weighted sound levels. Noise levels listed in Table 3.19-1 represent day-night sound levels (L_{dn}), an energy-averaged value over a 24-hour period that reflects increased sensitivity to noise when people are usually sleeping.

Existing sound levels in the areas of each project component are discussed below, as compared to the examples of typical noise levels shown in Table 3.19-1. For this analysis, an NSR is generally defined as an area where human use likely occurs, such as human dwellings, seasonal shelters, and temporary campsites (defined in more detail in Section 4.19, Noise). Native Allotments are the most likely types of land parcels that may have NSRs within the 2-mile analysis distance. These lands may be expected to include permanent or temporary structures to support a residence or hunting and fishing activities. Current definitive information regarding individual dwellings or other buildings is not available for all the Native Allotments; therefore, occurrence is used as a means to conservatively estimate NSRs in the analysis area by assuming all Native Allotments may have at least one NSR.

Table 3.19-1: Examples of Noise Levels

Outdoor	Noise Levels (dBA, L_{dn})	Indoor
Jet flying over at 1,000 feet	100	Rock band
Gas lawn mower at 3 feet	90	Blender at 3 feet
Next to busy highway	88	N/A
0.75 mile from touchdown at major airport	86	Garbage disposal at 3 feet
Noisy urban area during the day	70	Vacuum cleaner at 10 feet
Wooded suburban residential	51	Refrigerator at 3 feet
Rural residential	39	N/A
Wilderness Ambient	35	Library

Notes:

dBA = A-weighted decibel
L_{dn} = day-night sound level, expressed in dBA
N/A = not applicable
Source: EPA 1978; Caltrans 2009

Figure 3.19-1 shows the noise analysis area using the 10-mile distance for the mine site area and 2-mile distance for all other components for all alternatives, census-designated places (USCB 2017, 2018a, 2018c, 2018d), and Native Allotments.

The following sections describe the existing sound in areas for all alternatives, as well as a section summarizing potential NSRs associated with each alternative and variants. For the variants, both existing sound and potential NSRs are discussed in separate sections in comparison to Alternative 1a.

3.19.1 Alternative 1a

3.19.1.1 Mine Site—Existing Sound

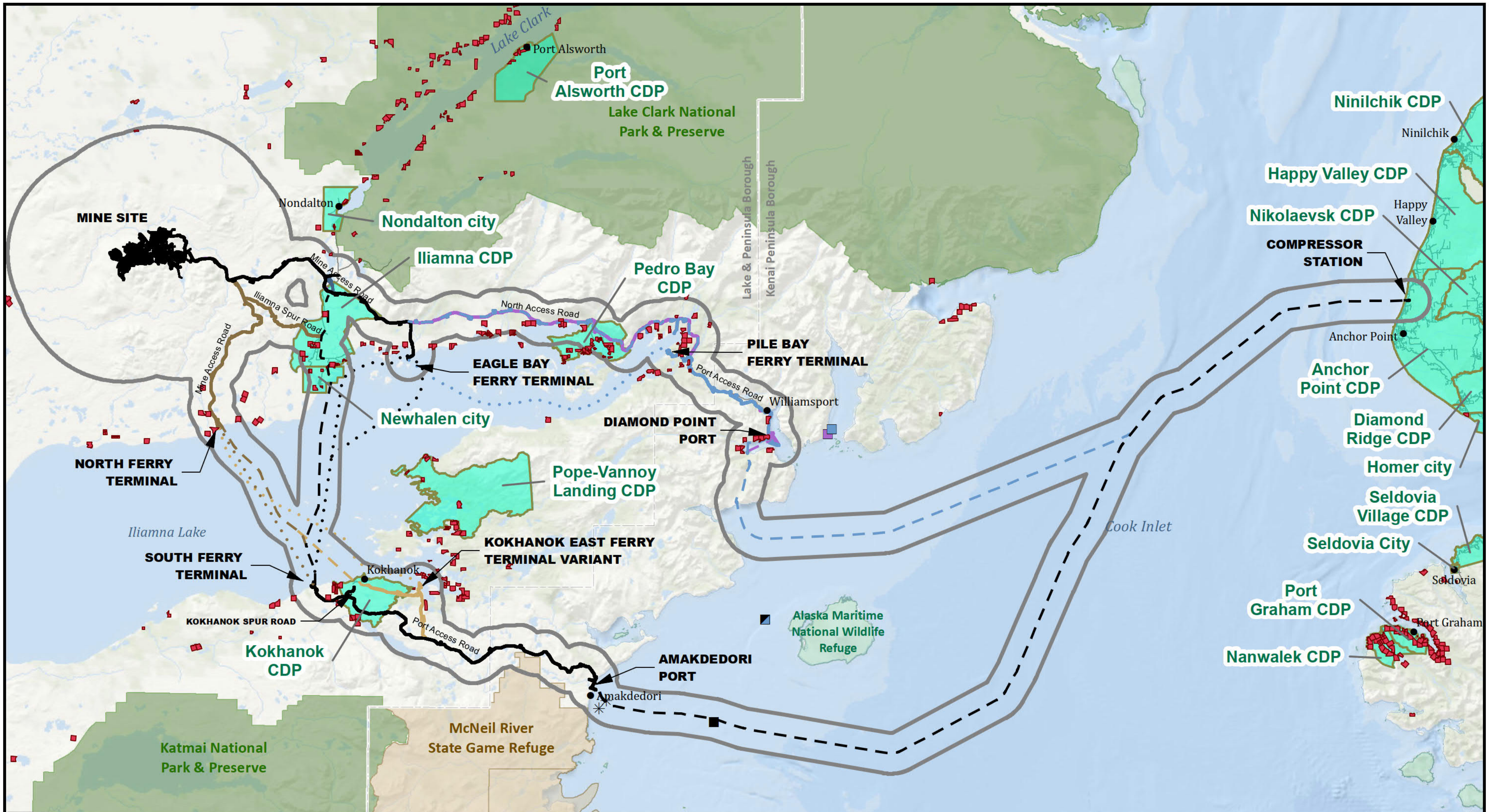
The mine site would be in a remote region of Alaska, characterized as having no development. No existing ambient sound data were collected in the vicinity of the mine site. However, data on ambient sound levels for generic land use types are available (Table 3.19-1). The values in Table 3.19-1 can be used to estimate the existing (pre-project) ambient sound level for corresponding land use types in the EIS analysis area. Due to its remoteness and lack of development, the existing land use in the vicinity of the mine site corresponds to the "wilderness ambient" classification in Table 3.19-1, with baseline ambient sound level of 35 L_{dn} (Table 3.19-2).

Table 3.19-2: Baseline Outdoor Sound Levels at Mine Site

Pebble Project Component	Baseline Outdoor Ambient Sound Level (dBA)	Basis
Mine site includes all features in the mine site footprint: open pit, mill and ore processing, water treatment plants, water management ponds, bulk and pyritic tailings storage facilities, power plant, utilities, services and infrastructure, mine maintenance, and safety controls.	35 L_{dn}	Typical L_{dn} for Wilderness (EPA 1978), L_{dn} for Outdoor Locations

Notes:

dBA = A-weighted decibel
L_{dn} = day-night sound level, expressed as dBA
Source: EPA 1978



Sources: PLP 2020-RFI168; PLP 2019-RFI153; USCB 2017, 2018a, b, c; USCB 2020; BLM 2018;ADNR

US Army Corps of Engineers

5 0 5 10
Miles

Noise Analysis Areas (10-mi analysis distance for Mine Site, 2-mi analysis distance for Other Infrastructure)

Native Allotments

Census-Designated Place

Action Alternatives

Lightering Locations

Ferry Routes

Natural Gas Pipelines

Alternative 1a

Alternative 1

Alternative 1 Kokhanok East Ferry Terminal Variant

Alternative 2

Alternative 2 Newhalen River North Crossing Variant

Alternative 3

Other Features

Local Roads

Borough Boundary

State Game Refuge/Sanctuary

Wild and Scenic River

National Wildlife Refuge

National Park

NOISE ANALYSIS AREAS

PEBBLE PROJECT EIS

FIGURE 3.19-1

3.19.1.2 Transportation Corridor—Existing Sound

For the purpose of describing existing sound levels, facilities in the transportation corridor are grouped and summarized according to location and use as described below.

Mine Site to Eagle Bay Ferry Terminal—As with the mine site, most of the mine access road would be in a remote area with no development. No ambient sound data were collected in the vicinity of the mine access road to Eagle Bay. Existing land use in the vicinity of the mine access road to Eagle Bay corresponds with the "wilderness ambient" classification in Table 3.19-1, with a baseline sound level of 35 dBA L_{dn}.

South Ferry Terminal—The vicinity of this Iliamna Lake shoreline area is undeveloped and is compatible with the "wilderness ambient" classification in Table 3.19-1, with a baseline sound level of 35 dBA L_{dn}. The ferry terminal and natural gas pipeline corridor would be 2 miles from the Gibraltar River outlet into Iliamna Lake. This area may be exposed to seasonal transportation noise sources such as small boat traffic for sport fishing during the summer, and possibly snowmachines during winter. No such motorized boats or vehicles would be expected during the shoulder seasons of freeze-up and break-up in the vicinity. These occasional or sporadic noise sources are conservatively ignored in assuming the "wilderness ambient" existing sound level.

Kokhanok Spur Road—Most of this spur road route is undeveloped and is compatible with the "wilderness ambient" classification in Table 3.19-1, with a baseline sound level of 35 dBA L_{dn}. Baseline sound level measurements were not collected in this vicinity. At the northern terminus of the spur road are an airstrip and the community of Kokhanok. Kokhanok is a census-designated place with a population of 140 residents (USCB 2018c), which could be considered "wilderness ambient" (Table 3.19-1). Not counting noise from occasional aircraft taking off and landing from the existing airstrip (an active public airport with Federal Aviation Administration [FAA] identifier "9K2"), the indicated level of 35 dBA L_{dn} would be conservative.

Port Access Road—The port access road would traverse an undeveloped area between Iliamna Lake and Cook Inlet at Amakdedori port and is compatible with the outdoor ambient sound level for the "wilderness ambient" classification in Table 3.19-1, with a baseline sound level of 35 dBA L_{dn}. No ambient sound data have been collected.

3.19.1.3 Amakdedori Port—Existing Sound

Baseline sound levels have not been measured at the Amakdedori port site. The vicinity of Amakdedori port is undeveloped and is compatible with outdoor ambient sound levels consistent with the "wilderness ambient" classification in Table 3.19-1, and baseline sound level of 35 dBA L_{dn}.

3.19.1.4 Natural Gas Pipeline Corridor—Existing Sound

For the purpose of describing existing sound levels, features along the natural gas pipeline corridor are grouped and summarized according to location, as described below.

Compressor Station near Anchor Point—The compressor station would be common to all alternatives. It is about 5 miles north of the town of Anchor Point and the 2-mile analysis distance from the compressor station partially includes the census-designated place, Anchor Point (USCB 2018a). The compressor station site is approximately 0.25 mile southeast of the Sterling Highway (Alaska Highway 1) near its intersection with Bourbon Avenue, where the pipeline would make landfall on the eastern side of Cook Inlet. Baseline sound levels were not measured in this vicinity. Using a Federal Transit Administration (FTA)-based estimation method that uses population density (21.2 people per square mile, based on US Census data) (USCB 2018a) as input, the baseline outdoor ambient sound level could be calculated as 35 dBA L_{dn}, a value comparable to the “wilderness ambient” designation(Table 3.19-1). The Sterling Highway is a major two-lane road that parallels the coast with minimum posted speed limits of 50 miles per hour; it would be expected to raise outdoor ambient sound levels to a minimum of 50 dBA L_{dn} about 1,000 feet from the road (which includes the compressor station site) per FTA guidance.

Amakdedori Port to South Ferry Terminal—This section of the pipeline corridor parallels the port access road. This portion of the corridor shares the same area and existing outdoor ambient sound environment with the port access road and is compatible with the “wilderness ambient” classification in Table 3.19-1, with a baseline sound level of 35 dBA L_{dn}.

Iliamna Lake to Mine Access Road—This would be a pipeline-only overland (buried) section from the north shore of Iliamna Lake, east of Newhalen to the mine access road on the eastern side of the Newhalen River. This pipeline corridor would pass between Newhalen and Iliamna, and pass within 1 mile of the Iliamna Airport. Existing outdoor sound levels were measured at position “M2,” about 2 miles north of the Iliamna Airport, as reported by Michael Minor and Associates (2010a) (Table 3.19-3). From measured L_{eq} data collected during daytime, evening, and nighttime periods at M2, and additional baseline field survey positions representing a variety of land uses (residential areas, a school, and a medical clinic), baseline L_{dn} values were calculated for the communities of Iliamna and Newhalen.

Table 3.19-3: Calculated Baseline Day-Night Sound Levels at Representative Iliamna and Newhalen Community Land Uses

Measurement Location (and Summary Description)	Summer Season L_{dn} (dBA)	Winter Season L_{dn} (dBA)
M2—Central Newhalen River Road (north of Iliamna Airport at the northernmost occupied residence on the Newhalen River Road)	53	47
M3—Iliamna Airport (near Iliamna Air Taxi terminal)	54	61
M4—Post Office and Community Medical Clinic (intersection of Iliamna Village Road and Newhalen Road)	51	52
M5—North Newhalen (residential area just off Newhalen Road)	47	42
M6—Newhalen School (in front of the school near Newhalen Road)	56	63
M7—Roadhouse Bed and Breakfast (and single-family residence on Iliamna Road)	47	42

Notes:

dBA = A-weighted decibel
L_{dn} = day-night sound level, expressed as dBA
Source: Michael Minor & Associates 2010a

Mine Access Road—The pipeline corridor would be along the mine access road and share the same area as the mine access road in a remote area with very little development; no ambient sound data were collected in the vicinity of the corridor. This portion of the pipeline corridor has an existing outdoor ambient sound environment that is compatible with the “wilderness ambient” classification in Table 3.19-1, with a baseline sound level of 35 dBA L_{dn}.

3.19.1.5 Alternative 1a—Sensitive Receptors

There are no sensitive receptors within 10 miles of the mine site. The 2-mile distance used for analysis of other Alternative 1a components includes 36 Native Allotments (3,140 acres) and partially includes the Kokhanok, Iliamna, and Anchor Point census-designated places (USCB 2017, 2018a, 2018c) (Figure 3.19-1).

3.19.2 Alternative 1

3.19.2.1 Mine Site—Existing Sound

The mine site existing sound would be the same as for Alternative 1a.

3.19.2.2 Transportation Corridor—Existing Sound

For the purpose of describing existing sound levels, facilities in the transportation corridor are grouped and summarized according to location and use as described below.

Mine Access Road to North Ferry Terminal—The mine access road would be in a remote area with no development. No ambient sound data were collected in the vicinity of the mine access road. Existing sound levels correspond with the "wilderness ambient" classification in Table 3.19-1, with a baseline sound level of 35 dBA L_{dn}.

Iliamna Spur Road—As with the mine access road, the spur road would be in a remote area with very little development. Aside from its southern terminus near Iliamna Airport, no ambient sound data were collected in the vicinity of the spur road; existing sound levels correspond with the "wilderness ambient" classification in Table 3.19-1, with a baseline sound level of 35 dBA L_{dn}. Existing outdoor sound levels were measured at position "M2," about 2 miles north of Iliamna Airport, as reported in Michael Minor & Associates (2010a) (Table 3.19-3). Baseline L_{dn} values were calculated for the communities of Iliamna and Newhalen using measured L_{eq} data collected during daytime, evening, and nighttime periods at M2, as well as additional baseline field survey positions representing a variety of land uses (residential areas, a school, and a medical clinic).

Kokhanok Spur Road—Baseline sound would be the same as for Alternative 1a.

North Ferry Terminal—This area, in the vicinity of the Iliamna Lake shoreline, is undeveloped and compatible with the "wilderness ambient" classification in Table 3.19-1, with a baseline sound level of 35 dBA L_{dn}. Baseline sound level measurements were not conducted in this vicinity. The north ferry terminal and natural gas pipeline corridor would be within 1 mile of the Upper Talarik Creek outlet into Iliamna Lake. This area may be exposed to seasonal transportation noise sources, such as small boat traffic for sport fishing during the summer, and possibly snowmachines during winter. No motorized boats or vehicles would be expected in the area during the shoulder seasons of freeze-up and break-up. These occasional or sporadic noise sources are conservatively ignored in assuming the "wilderness ambient" existing sound level.

3.19.2.3 Amakdedori Port—Existing Sound

Baseline sound would be the same as for Alternative 1a.

3.19.2.4 Natural Gas Pipeline Corridor—Existing Sound

Compressor Station near Anchor Point—Baseline sound at the compressor station at Anchor Point would be the same as for Alternative 1a.

Mine Site to Amakdedori Port—This section of the pipeline corridor parallels the mine access road, north and south ferry terminals, port access road, and Amakdedori port site. This portion of the corridor shares the same area and existing outdoor ambient sound environment with these project components and is compatible with the "wilderness ambient" classification in Table 3.19-1, with a baseline sound level of 35 dBA L_{dn}.

3.19.2.5 Alternative 1—Sensitive Receptors

There are no sensitive receptors within 10 miles of the mine site. The 2-mile distance used for analysis of other Alternative 1 components includes 22 Native Allotments (2,755 acres) and partially includes the Kokhanok, Iliamna, and Anchor Point census-designated places (USCB 2017, 2018a, 2018c) (Figure 3.19-1).

3.19.2.6 Alternative 1—Summer-Only Ferry Operations Variant

Baseline sound conditions and potential NSRs under this variant would be the same as those described for Alternative 1.

3.19.2.7 Alternative 1—Kokhanok East Ferry Terminal Variant

Existing Sound

The Kokhanok east ferry terminal site would be about 6.5 miles east of the south ferry terminal site described for Alternative 1a and Alternative 1 (see Chapter 2, Alternatives). Section 3.9, Subsistence, describes conditions and activity in the vicinity of the Kokhanok east ferry terminal that may contribute to background sound, including seasonal use of boats, snowmachines, and all-terrain-vehicles. Except for sounds associated with these sources, the outdoor ambient sound level would be the same baseline sound level of 35 dBA L_{dn}.

Sensitive Receptors with Variant

Evaluated data sets used to identify potential NSRs are described in AECOM 2018c. The 2-mile analysis distance for this variant includes 22 Native Allotments (2,555 acres) and partially includes the Kokhanok and Anchor Point census-designated places (USCB 2018a, c).

3.19.2.8 Alternative 1—Pile-Supported Dock Variant

Existing sound conditions and potential NSRs would be the same as those described for Alternative 1.

3.19.3 Alternative 2—North Road and Ferry with Downstream Dams

3.19.3.1 Mine Site—Existing Sound

Existing sound conditions and potential NSRs would be the same as those described for Alternative 1a.

3.19.3.2 Transportation Corridor—Existing Sound

For the purpose of describing existing sound levels, facilities in the transportation corridor are grouped and summarized according to location as described below.

Mine Access Road to Eagle Bay—Baseline sound in the road corridor from the mine site to Eagle Bay would be the same as for Alternative 1a.

Eagle Bay Ferry and Pile Bay Ferry Terminals—No ambient sound data were collected in these areas. These Iliamna Lake shoreline areas are generally undeveloped and would be compatible with the "wilderness ambient" classification in Table 3.19-1, with a baseline sound level of 35 dBA L_{dn}.

Port Access Road—No ambient sound data were collected in this area, which has little development. The road would connect the Pile Bay ferry terminal to the Diamond Point port, bypassing all but 5 miles of the existing Williamsport-Pile Bay Road. The existing road is primarily used by large tractor-trailer rigs in the summer season to haul boats and other bulky freight between Iliamna Lake and Cook Inlet. Other than the existing road segment, there is little development, and the baseline outdoor ambient sound level is “wilderness ambient” classification in Table 3.19-1, with a baseline sound level of 35 dBA L_{dn}. Infrequent truck traffic on the existing Williamsport-Pile Bay Road would temporarily raise the outdoor ambient sound level near the route.

3.19.3.3 Diamond Point Port—Existing Sound

Based on site observations (AECOM 2018h), development in the vicinity of the Diamond Point port is associated with a gravel and rock quarry. According to Special Condition #6 on the US Army Corps of Engineers (USACE) permit (POA-2008-523) (USACE 2012), seasonal activities are permitted from May 1 to October 31 each year. Depending on the progress of tideland fill and the corresponding pace of gravel and rock material production, noise-producing activities could include dredging, pile-driving, rock blasting, distribution of materials, and the operation of equipment, consistent with the description in POA-2008-523. Material extracted from the quarry would be transported via marine route. There would be no quarry-associated vehicle traffic contributing to baseline noise conditions on the port access road (see above under port access road). One or more of these noise-producing sources would temporarily elevate outdoor ambient sound levels to a degree that would depend largely on the distance between the receptor location and the source of the noise-producing activity or event.

Outside of this permitted site development activity, little or no noise-producing activities occur at the Diamond Point port site. This suggests that outdoor ambient sound levels would reflect naturally occurring acoustical contributors and be more consistent with the “wilderness ambient” classification in Table 3.19-1, with a baseline sound level of 35 dBA L_{dn}. Depending on proximity to the Cook Inlet shoreline and the magnitude of winds and wave activity, localized sound levels may be higher. Baseline sound levels have not been measured at this location.

3.19.3.4 Natural Gas Pipeline Corridor—Existing Sound

Existing sound conditions are addressed by location along the natural gas pipeline corridor as described below.

Compressor Station near Anchor Point—Baseline sound conditions in the vicinity of the compressor station would be the same as those described for Alternative 1a.

Mine Site to Diamond Point Port—This overland section of the pipeline corridor would parallel the north route mine access road (see Chapter 2, Alternatives). Existing outdoor baseline sound levels are compatible with the “wilderness” classification in Table 3.19-1, with a baseline sound level of 35 dBA L_{dn}.

Ursus Cove to Diamond Point Port—The pipeline would be buried onshore between Ursus Cove and Cottonwood Cove, installed in the seabed across Cottonwood Cove via trenching methods (see Chapter 2, Alternatives), and connect to the onshore portion at the Diamond Point port. The area represented by this pipeline section is undeveloped and is compatible with the “wilderness ambient” classification in Table 3.19-1, with a baseline sound level of 35 dBA L_{dn}.

3.19.3.5 Alternative 2—Sensitive Receptors

Evaluated data sets used to identify potential NSRs are described in AECOM 2018c. The 2-mile analysis distance includes 76 Native Allotments (6,053 acres), and passes through a portion of

Iliamna, Pedro Bay, and Anchor Point census-designated places (USCB 2017, 2018a, USCB 2020).

3.19.3.6 Alternative 2—Summer-Only Ferry Operations Variant

Existing sound conditions and potential NSRs would be the same as those described for Alternative 2.

3.19.3.7 Alternative 2—Pile-Supported Dock Variant

Existing sound conditions and potential NSRs would be the same as those described for Alternative 2

3.19.3.8 Alternative 2—Newhalen River North Crossing Variant

Existing sound conditions and potential NSRs would be the same as those described for Alternative 2.

3.19.4 Alternative 3—North Road Only

3.19.4.1 Mine Site—Existing Sound

Existing sound conditions and potential NSRs would be the same as those described for Alternative 1a.

3.19.4.2 Transportation Corridor—Existing Sound

For the purpose of describing existing sound levels, facilities in the transportation corridor are grouped and summarized according to location as described below.

Mine Access Road—Most of the mine access road is remote, with no development. Along the undeveloped portion of the overland transportation route, the "wilderness ambient" classification in Table 3.19-1, with a baseline sound level of 35 dBA L_{dn}. Pedro Bay is a village along the north route, where existing outdoor sound levels were measured at positions M10, M11, and M12 (Michael Minor & Associates 2010a). From measured L_{eq} data collected during daytime, evening, and nighttime periods at these three positions, calculated baseline L_{dn} values for the Pedro Bay community are shown in Table 3.19-4.

Table 3.19-4: Calculated Baseline Day-Night Sound Levels at Representative Pedro Bay Community Land Uses

Measurement Location (and Summary Description)	Summer Season L_{dn} (dBA)	Winter Season L_{dn} (dBA)
M10—Pedro Bay on Iliamna Lake (along the shoreline next to several cabins used for fishing trips and where several floatplanes were moored)	48	42
M11—Pedro Bay Tribal Center (behind Tribal Center, up the hill)	48	40
M12—Pedro Bay School (on school grounds near the main school entrance; additional readings taken behind school at power plant)	44	44

Notes:

dBA = A-weighted decibel
L_{dn} = day-night sound level, expressed as dBA
Source: Michael Minor & Associates 2010a

3.19.4.3 Diamond Point Port—Existing Sound

Existing sound conditions and potential NSRs would be the same as described for Alternative 2.

3.19.4.4 Natural Gas Pipeline Corridor—Existing Sound

For the purpose of describing existing sound levels, features along the natural gas pipeline corridor are grouped and summarized according to location as described below.

Anchor Point—Baseline sound would be the same as that described for Alternative 1a.

Mine Site to Diamond Point Port—This section of the pipeline would parallel the mine access road and north access pipeline corridor as described for Alternative 2; would share the same area and existing outdoor ambient sound environment with the mine access road, and is compatible with the "wilderness ambient" classification in Table 3.19-1, with a baseline sound level of 35 dBA L_{dn}. There may be localized higher L_{dn} values in the vicinity of Pedro Bay (Table 3.19-4).

Ursus Cove to Diamond Point Port—Baseline sound would be the same as that described for Alternative 2.

3.19.4.5 Alternative 3—Sensitive Receptors

Evaluated data sets used to identify potential NSRs are described in AECOM 2018c. There are no sensitive receptors within 10 miles of the mine site. The 2-mile analysis zone of all other Alternative 3 project components includes 71 Native Allotments (5,702 acres), and partially includes the Iliamna, Pedro Bay, and Anchor Point census-designated places (USCB 2017, 2018a, 2020).

3.19.4.6 Alternative 3—Concentrate Pipeline Variant

Under this variant, baseline sound conditions and identified NSRs would be the same as described above for the natural gas pipeline corridor for Alternative 3.

3.19.5 Comparison of Sensitive Receptors by Alternative

Table 3.19-5 provides a comparative summary of the analysis area for each alternative and variant within a 10-mile analysis distance of the mine site, and a 2-mile analysis distance for all other project components (Figure 3.19-1). The analysis distance would encompass the conservative area in which noise impacts could potentially occur, as described in Section 4.19, Noise. Table 3.19-5 lists the number and acreage of Native Allotments associated with each alternative and variant, as well as their proximity to census-designated places.

Table 3.19-5: Comparison of Potential Noise-Sensitive Receptors by Alternative

Alternative and Variant	Analysis Area[1]	Native Allotments		Proximity to Census Designated Places[1]			
	Acres	Count	Acres	Iliamna	Kokhanok	Pedro Bay	Anchor Point
Alternative 1a	849,953	36	3,140	Yes	Yes	No	Yes
Alternative 1 (Main)	806,073	22	2,755	Yes	Yes	No	Yes
Alternative 1—Kokhanok East Ferry Terminal Variant	801,615	22	2,555	Yes	Yes	No	Yes
Alternative 1—Summer-Only Ferry Operations Variant	806,069	22	2,755	Yes	Yes	No	Yes
Alternative 1—Pile-Supported Dock Variant	806,068	22	2,755	Yes	Yes	No	Yes
Alternative 2 (Main)	757,370	76	6,053	Yes	No	Yes	Yes
Alternative 2 Newhalen River North Crossing Variant	756,586	76	6,053	Yes	No	Yes	Yes
Alternative 2 Summer-Only Ferry Operations Variant	757,369	76	6,053	Yes	No	Yes	Yes
Alternative 2—Pile-Supported Dock Variant	757,373	76	6,053	Yes	No	Yes	Yes
Alternative 3 (Main)	744,708	71	5,702	Yes	No	Yes	Yes
Alternative 3—Concentrate Pipeline Variant	744,708	71	5,702	Yes	No	Yes	Yes

Note:

[1]10-mile analysis distance from mine site and 2-mile analysis distance for other components

Source: PLP 2018d; USCB 2017, 2018a, 2018c, 2020

3.20 AIR QUALITY

This section describes the current air quality for the Environmental Impact Statement (EIS) analysis area. The EIS analysis area for air quality analysis encompasses the mine site, port, transportation corridor, and natural gas pipeline corridor for each alternative and variants, as well as the larger geographical area that would experience indirect impacts. The air quality analyses presented are applicable for all alternatives, because they are generally in the same area.

3.20.1 Regional Air Quality

Air quality is defined by the concentration of criteria pollutants and their interactions in the atmosphere, Hazardous Air Pollutants (HAPs), and the magnitude of haze and acidic deposition generally referred to as Air Quality Related Values (AQRVs). An understanding of current conditions and trends of these air quality metrics also provides a baseline for comparison of potential future impacts. Recent trends in air quality are important to consider when evaluating potential future changes, independent of an individual project.

Air quality is assessed through the analysis of values measured by the monitors listed in Table 3.20-1. A map of the monitor locations is presented in Figure 3.20-1. Criteria pollutants were analyzed using data obtained from the Alaska Department of Environmental Conservation (ADEC). Existing visibility conditions were assessed using monitors from the Interagency Monitoring of Protected Environment (IMPROVE) network. The wet and dry deposition measurements are collected by the National Acid Deposition Program (NADP) and the Clean Air Status and Trends Network (CASTNET), respectively. Except for Denali National Park monitors, all monitors are within 200 miles of the mine site, which is typically close enough to be considered representative of the area.

3.20.1.1 Criteria Pollutants

The relative importance of criteria pollutant concentrations can be determined by comparison with the Alaska Ambient Air Quality Standards (AAAQS), which are equivalent to, or more stringent than, the National Ambient Air Quality Standards (NAAQS). Air pollutant concentrations that are lower than the AAAQS provide public health protection, including protecting the health of sensitive populations such as asthmatics, children, and the elderly. In the region containing the analysis area, all pollutants are below the AAAQS. With the exception of locations near airfields, where lead emissions from aircraft exhaust has the potential to occur, regional sources of lead are minimal. Because the project is far from any airfields where lead emissions could occur, and potential project lead emissions are extremely low, ambient lead concentrations and comparisons to the lead AAAQS are not addressed further in this analysis.

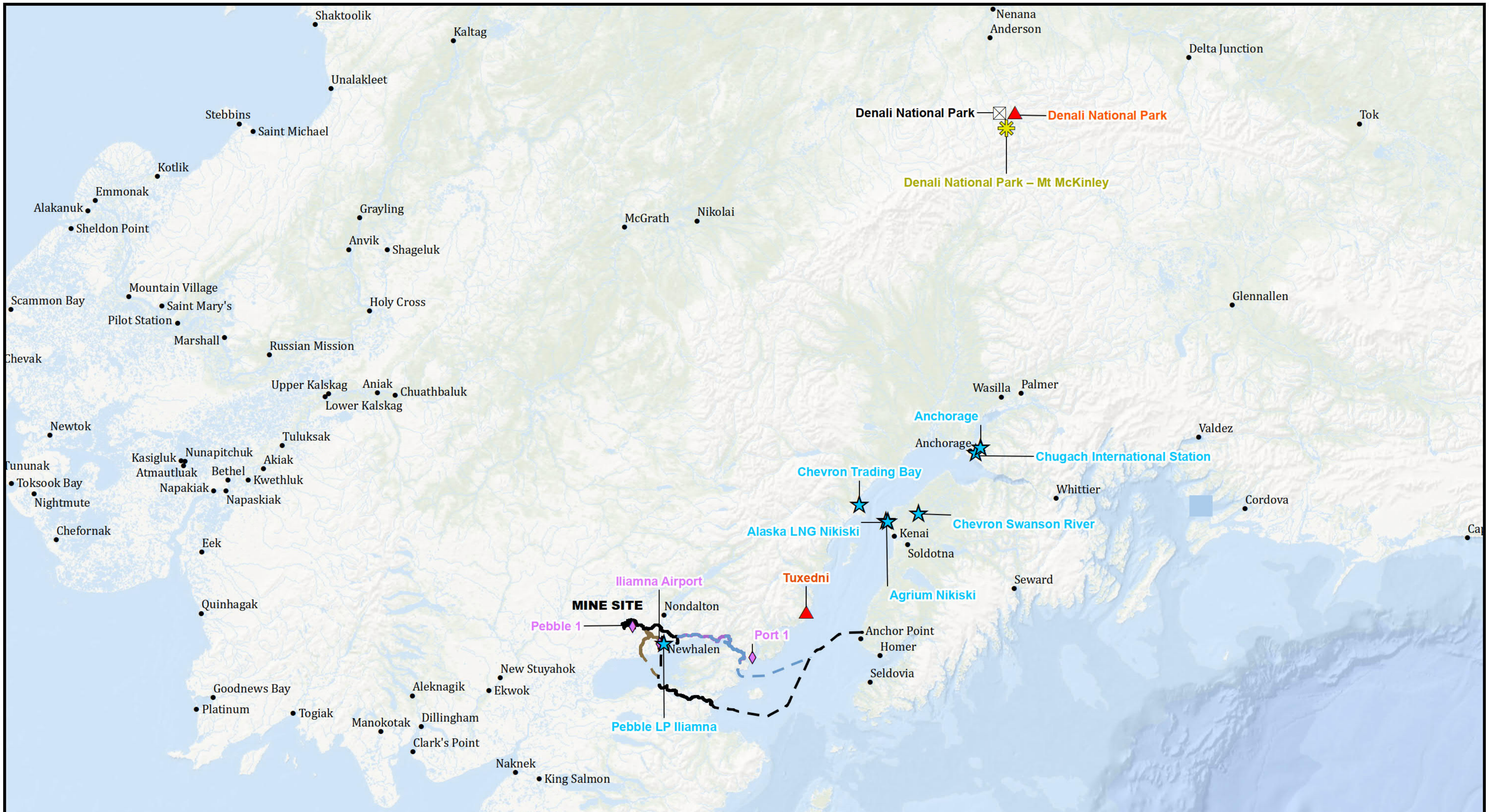
The Alaska Air Monitoring Network measures certain criteria pollutants of interest throughout Alaska, and can be used to assess the general air quality trends of the region. The nearest of these monitors are in relatively urbanized areas in and around Anchorage, and are distant from the analysis area (ADEC 2016a). Due to the increased anthropogenic activity, measurements at these monitors are expected to be elevated compared to what should be observed in the analysis area; however, the long-term measurement record available from this network can provide a valuable understanding of regional trends. The Alaska Air Monitoring Network only measures particulate matter with an aerodynamic diameter less than or equal to 10 microns (PM_{10}), particulate matter with an aerodynamic diameter less than or equal to 2.5 microns ($PM_{2.5}$), ozone, and carbon monoxide (CO) close enough to the analysis area to be relevant. For the remaining criteria pollutants, long-term trends are not available for analysis.

Table 3.20-1: Monitor Name and Details Used in the Analysis

Network	Monitor Name	Monitoring Period	Monitored Parameters[1]	Monitor Purpose[2]	Approximate Distance from Mine Site
Private Industry Monitors[3]	Chevron Trading Bay	2008-2009	NO_2, CO	Maximum Impact	130 miles east
	Chevron Swanson River	2008-2009	NO_2, CO	Maximum Impact	160 miles east
	Agrium Nikiski	2013-2014	PM_{10}, $PM_{2.5}$, ozone	Maximum Impact	140 miles east
	Alaska LNG Nikiski	2015	NO_2, CO, PM_{10}, $PM_{2.5}$, SO_2, ozone	Background	140 miles east
	Chugach International Station	2011-2012	NO_2, ozone	Maximum Impact	200 miles east-southeast
	PLP Iliamna	2012-2013	NO_2, CO, PM_{10}, $PM_{2.5}$, SO_2, ozone	Background	30 miles southeast
Alaska Air Monitoring Network[4]	Select Anchorage monitors	2000-2014	$PM_{2.5}$, PM_{10}, ozone, CO	Background	180 miles east
IMPROVE[5]	Tuxedni	2008-2014	Visibility	Background	80 miles southeast
	Denali National Park	2008-2016	Visibility	Background	330 miles northeast
CASTNET[6]	Denali National Park	1999-2016	Dry Deposition	Background	330 miles northeast
NADP[7]	Denali National Park—Mount McKinley	1999-2015	Wet Deposition	Background	330 miles northeast

Notes:

[1]NO_2 = nitrogen dioxide, CO = carbon dioxide, PM_{10} = PM particulate matter with an aerodynamic diameter less than or equal to 10 microns, $PM_{2.5}$ = PM particulate matter with an aerodynamic diameter less than or equal to 2.5 microns, SO_2 = sulfur dioxide
[2]For the purpose of monitors presented, the data are collected either to provide background data or to capture maximum impacts from emission sources near the monitor location
[3]Data Obtained from ADEC 2018c
[4]ADEC 2016a
[5]IMPROVE 2018a, b
[6]EPA 2018b
[7]NADP 2018



Sources: PLP 2020-RFI168; PLP 2019-RFI153; ADEC, Alaska Air; IMPROVE; CASTNeT; NADP; Hoefler 2010a; WRCC

US Army Corps of Engineers

25 0 25 50

Miles

Station Type

- Air Quality
- CastNet
- IMPROVE
- Meteorological
- NADP

Action Alternatives

- Natural Gas Pipelines
- Alternative 1a
- Alternative 1
- Alternative 2
- Alternative 3

RELEVANT AIR QUALITY MONITORING STATIONS

PEBBLE PROJECT EIS

FIGURE 3.20-1

For $PM_{2.5}$ and PM_{10}, the frequency of AAAQS exceedances has increased since 2000 (ADEC 2016a). ADEC documents that this increase is due to an increase in the frequency of wildfires near the monitors. The more rural monitors that collect measurements are a closer representation of the analysis area, but are still higher than what would be expected given their proximity to sources; the measured concentrations have remained relatively constant, with reported annual $PM_{2.5}$ values near 6.5 micrograms per cubic meter ($\mu g/m^3$), and well below the AAAQS. The measured CO concentrations at the Anchorage monitor decreased to values consistently below 6 parts per million (ppm) from 2000 to 2014 (ADEC 2016a). An assessment of 4 years of ozone measurements at monitoring sites near Anchorage indicates that hourly ozone concentrations peak in the late spring and are lowest in winter (ADEC 2016a). This is consistent with global trends for this latitude.

Table 3.20-2 lists existing conditions measured at locations near the project study area, shown for all criteria pollutants except lead. Compared to the Anchorage monitors previously discussed, with the exception of the Chugach International Station, these monitors are in more remote areas, with fewer anthropogenic sources, aside from those associated with the large industrial facilities the data collection efforts were designed to support. None of the monitoring programs documented in Table 3.20-2 represent more than 1 year of data; therefore, multi-year averages that are required for the 1-hour nitrogen dioxide (NO_2), 1-hour sulfur dioxide (SO_2), and $PM_{2.5}$ AAAQS cannot be properly calculated. For those pollutants and averaging periods, the values presented in Table 3.20-2 are not directly comparable to the AAAQS, but are still a reliable indicator of recent air quality, and show if values in the vicinity of the analysis area are near AAAQS thresholds; however, a single year of data could represent an anomalous event.

All values listed in Table 3.20-2 are well below the AAAQS. Unlike the measurement locations themselves, the analysis area is far from large industrial emissions sources, with relatively sparse population. Therefore, measured concentrations in the analysis area are expected to be lower.

Secondary NAAQS set limits to protect public welfare, including protection against decreased visibility; endangerment to animals; and damage to crops, vegetation, and buildings. In most cases, the AAAQS are also protective of the health of plant and animal species because they are equal to or more stringent than the secondary NAAQS; however, for some species of lichens, which can be particularly sensitive to SO_2, ADEC (2016b) recommends supplementing these standards with an annual SO_2 threshold of 13 $\mu g/m^3$, which is more stringent than the annual SO_2 AAAQS. Annual SO_2 concentrations at the Alaska Liquefied Natural Gas (LNG) Nikiski monitor are reported as zero (Table 3.20-2), indicating that concentrations are less than 0.0005 ppm (1.4 $\mu g/m^3$), and well below the annual SO_2 threshold of 13 $\mu g/m^3$. Given that the analysis area has limited sources of anthropogenic SO_2, it is expected that the SO_2 concentrations in the analysis area would be similar to those measured at the Alaska LNG Nikiski monitor.

Table 3.20-2: Criteria Pollutant Data Complied by ADEC

Pollutant	Averaging Period	Rank[1]	AAAQS	Monitor Name					
				Chevron Trading Bay	Chevron Swanson River	Agrium Nikiski	Alaska LNG Nikiski	Chugach International Station	PLP Iliamna
NO_2	1-hour	98th Percentile of Daily Max	100 ppb	N/A	N/A	N/A	16.0 ppb	80.7 ppb	7.0 µg/m^3
	Annual	Maximum Annual Average	53 ppb	3.0 ppb	7.0 ppb	N/A	1.0 ppb	15 ppb	0 µg/m^3
SO_2	1-hour	99th Percentile of Daily Max	75 ppb	N/A	N/A	N/A	1.6 ppb	N/A	N/A
	3-hour	Second High	0.5 ppm	N/A	N/A	N/A	0 ppm	N/A	N/A
	24-hour	Second High	0.14 ppm	N/A	N/A	N/A	0 ppm	N/A	N/A
	Annual	Maximum Annual Average	0.030 ppm	N/A	N/A	N/A	0 ppm	N/A	N/A
PM_{10}	24-hour	Second High	150 µg/m^3	N/A	N/A	58.5 µg/m^3	30.0 µg/m^3	N/A	12.4 µg/m^3
$PM_{2.5}$	24-hour	98th Percentile	35 µg/m^3	N/A	N/A	8.0 µg/m^3	12 µg/m^3	N/A	4.1
	Annual	Maximum Annual Average	12 µg/m^3	N/A	N/A	3.6 µg/m^3	3.7 µg/m^3	N/A	0.9
CO	1-hour	Second High	35 ppm	1.5 ppm	1.7 ppm	N/A	1 ppm	N/A	N/A
	8-hour	Second High	9 ppm	1 ppm	0.9 ppm	N/A	1 ppm	N/A	686.0 µg/m^3
Ozone	8-hour	Fourth High	0.070 ppm	N/A	N/A	0.051 ppm	0.047 ppm	0.047 ppm	102.4 µg/m^3

Notes:
[1]As reported by ADEC. See ADEC 2019b for more information on calculations and applicability to direct comparisons to AAAQS
AAAQS = Alaska Ambient Air Quality Standards
ADEC = Alaska Department of Environmental Conservation
CO = carbon dioxide
LNG = liquefied natural gas
µg/m^3 = micrograms per cubic meter
N/A = not available
NO_2 = nitrogen dioxide
PM_{10} = particulate matter with an aerodynamic diameter less than or equal to 10 microns
$PM_{2.5}$ = particulate matter with an aerodynamic diameter less than or equal to 2.5 microns
ppb = parts per billion
ppm = parts per million
SO_2 = sulfur dioxide

3.20.1.2 Hazardous Air Pollutants

HAPs can cause serious health effects or adverse environmental or ecological effects. Concentrations of HAPs are rarely measured, and there are no monitors measuring HAPs in the region; therefore, no data are available to assess the current concentrations or trends. HAPs are not generally measured, except in the vicinity of very specific large sources, such as refineries. The HAPs of primary concern are reactive and short-lived in the atmosphere. Therefore, absent large regional anthropogenic sources, there is no reason to expect measurable concentrations in the analysis area, except for what is biogenic in nature. For the same reasons, increasing or decreasing trends over time of HAPs in the analysis area are not expected.

3.20.1.3 Air Quality Related Values

Thresholds for AQRVs have been set to protect resources sensitive to acidic deposition and visibility degradation. These resources include vegetation, soils, water, fish, wildlife, and recreation. Visibility and deposition are reviewed in more detail below for the purpose of establishing baseline conditions pertinent to vegetation, soils, water, fish, and recreation.

Visibility

Visibility impairment primarily impacts the recreational value of a location, and is not a concern for vegetation, soil, water, and fish. Regional haze is a visibility impairment caused by the cumulative air pollutant emissions from numerous sources over a wide geographic area. Visibility impairment is caused by particles and gases in the atmosphere that scatter or absorb light. Light scattering is the primary cause of regional haze in many parts of the country, resulting from fine particles (e.g., $PM_{2.5}$) in the atmosphere. Additionally, coarse particles between 2.5 and 10 microns in diameter can contribute to both light absorption and scattering, increasing regional haze. Coarse particles and $PM_{2.5}$ can be naturally occurring, or the result of human activity. The natural levels of coarse particles result in some level of visibility impairment in the absence of any human influences, and vary with season, daily meteorology, and geography (Malm 1999).

The US Environmental Protection Agency (EPA) and other agencies have been monitoring visibility in national parks and wilderness areas since 1988. Observations have shown that visibility at national parks and wilderness areas throughout the US was not as good as estimated natural background conditions (i.e., visibility is impaired relative to natural background conditions). The Regional Haze Rule was promulgated by the EPA in 1999 to establish Reasonable Progress Goals for improving visibility (EPA 2018c).

ADEC (2011) has determined that a primary source of visibility degradation for Alaska is short- and long-range transport of dust, and transport of combustion emissions from anthropogenic sources in Asia and northern Europe. The long-range transport of dust across the Pacific Ocean typically influences visibility in Alaska in spring and summer, while anthropogenic emissions from northern Europe and Russia reach Alaska during the winter and early spring. Additionally, particulate and gaseous emissions from wildfires influence visibility throughout Alaska. Wildfire season typically starts once snow melt occurs in late spring and ends in early fall (ADEC 2011).

Visibility impacts are expressed in deciviews (dv), which is a measure for describing perceived changes in visibility. Deciview values are calculated from either measured or estimated light extinction values in units of inverse megameters (Mm^{-1}). The smaller the dv value, the more pristine the atmosphere, and the greater distances that can be seen without visibility obstruction increasing, resulting in large visual range values. An estimate of 11 dv typically results in a visual range of 80 miles, while an estimate of 3 dv results in a visual range of 180 miles.

The IMPROVE program has calculated haze index values (expressed as dv) for the 20 percent best days (i.e., clearest), 20 percent worst days (i.e., haziest), and natural conditions. The natural condition haze index is an estimate of average visibility that would occur in an area during natural conditions. According to IMPROVE 2019 “natural conditions” are “prehistoric and pristine atmospheric states (i.e., atmospheric conditions) that are not affected by human activities.”

Using these metrics, visibility in the analysis area was inferred from the two closest visibility monitoring stations operated by the IMPROVE program, as listed in Table 3.20-1. Visibility values for the 20 percent best days, 20 percent worst days, and natural conditions are shown in Table 3.20-3 for these two IMPROVE stations during the period from 2011 to 2016, noting that the Tuxedni monitor does not have data after 2014.

Data in Table 3.20-3 indicate that for either the Tuxedni or Denali National Park monitor, the haziest days generally have haze index values between 7 and 13 dv, while the clearest days typically have haze index values less than 5 dv. When comparing the current haze index values at either monitoring station to the estimated natural conditions haze index values, both the haziest and clearest days have slightly worse visibility than those found under natural conditions.

Overall, at the Tuxedni monitor, which is closest to the analysis area, the annual average haze index is closer to the natural conditions on both the haziest and clearest days; whereas the measured visibility at Denali National Park is worse compared to the natural condition for both the haziest and clearest days. However, the values measured in 2016 are comparable to the natural conditions. Most importantly, regardless of the location, visibility has been steadily trending toward natural conditions.

Table 3.20-3: Visibility Values by Year

Monitor Name	Type	Annual Average Measured Haze Index (deciview)						
		2011	2012	2013	2014	2015	2016	Natural Condition Haze Index
Tuxedni	Haziest Days	12.3	11.6	12.4	13.2	N/A	N/A	11.3
	Clearest Days	4.3	3.9	3.6	3.8	N/A	N/A	3.1
Denali National Park	Haziest Days	9.1	8.7	9.6	8.6	12	7.3	7.3
	Clearest Days	2.7	2.7	2.2	2.3	2.2	1.9	1.8

Notes:
N/A = not available
Source: IMPROVE 2018a, b

Deposition

Deposition can be from both wet and dry processes. Wet deposition refers to acidic rain, fog, and snow; dry deposition refers to gases and particles the wind blows onto buildings, cars, homes, and trees. The effects of atmospheric deposition of nitrogen and sulfur compounds on terrestrial and aquatic ecosystems are well-documented for some ecosystems and have been shown to cause leaching of nutrients from soils, acidification of surface waters, injury to high-elevation vegetation, and changes in nutrient cycling and species composition. Given that the project would contribute minimal sulfur compounds to the atmosphere, it is not anticipated that the effects of acidification through sulfur deposition would be prevalent due to the project. Therefore, the focus of the atmospheric deposition discussion is on nitrogen deposition, because the project would emit nitrogen compounds to the atmosphere.

In Alaska, deposition is routinely measured at Denali National Park. However, given that both SO_2 and NO_x emissions contribute to both visibility impairment and deposition, and knowing that visibility degradation in Denali National Park is slightly worse than at Tuxedni, it is expected that deposition measurements in Denali National Park are conservatively representative of Tuxedni and the analysis area. Wet deposition measurements at Denali National Park are collected by NADP in micro-equivalent per liter (μeq/l), and dry deposition is estimated from ambient measurements collected by CASTNET in kilograms per hectare (kg/ha). Deposition measurements in Denali National Park indicate that total sulfate and nitrate wet deposition rates have slowly decreased since the start of the record, while dry deposition rates have remained relatively unchanged (Table 3.20-4).

Table 3.20-4: Wet and Dry Deposition at Denali National Park Monitoring Location

Year	Wet Deposition (μeq/l)[1]		Dry Deposition (kg/ha)[2]	
	Sulfur	Nitrogen	Sulfur	Nitrogen
2016	N/A	N/A	0.2	0.2
2015	1.8	1.5	0.2	0.3
2014	3.7	1.9	0.2	0.3
2013	2.5	1.5	0.2	0.3
2012	2.3	1.5	0.2	0.2
2011	2.4	1.0	0.2	0.2
2010	3.2	2.3	0.2	0.2
2009	6	1.7	0.3	0.4
2008	2.6	1.3	0.2	0.2
2007	3.4	1.2	0.2	0.3
2006	3.7	1.4	0.3	0.3
2005	3	2.2	0.2	0.4
2004	3.2	2	0.3	0.5
2003	3.1	2.4	0.3	0.3
2002	6.5	3.5	0.2	0.4
2001	4.6	2.9	0.3	0.3
2000	3.5	1.7	0.2	0.3
1999	2.2	2	0.3	0.3

Notes:
[1] Wet Deposition for station AK03 (NADP 2018)
[2] Dry Deposition for station DEN417 (EPA 2018b)
kg/ha = kilograms per hectare
μeq/l = micro-equivalent per liter

As discussed, for Alaska the focus is on nitrogen deposition. Currently, the National Park Service (NPS) is recommending the use of nutrient nitrogen-critical loads for the evaluation of deposition impacts in terrestrial and aquatic ecosystems. The nutrient nitrogen critical load thresholds are a tool used to assess and understand the impacts of nitrogen deposition to ecosystems. The nitrogen-critical loads are determined by amount of nitrogen deposition below which no harmful effects to an ecosystem are expected. This value varies based on the type of ecosystem present in an area. Estimates of nitrogen-critical load values in Denali National Park range from

1.2 kilograms of nitrogen per hectare per year (kgN/ha/yr) for lichens and bryophytes, to 17.0 kgN/ha/yr for forests and nitrate leaching (NPS 2018b). Although additional information would be needed to convert the wet deposition rates into appropriate units for comparison to critical load values, the estimates of dry deposition at Denali National Park are well below the lowest critical load value of 1.2 kgN/ha/yr (Table 3.20-4). The same is expected for the analysis area.

3.20.2 Regional Climate

The analysis area is in a transitional climatic zone with a strong maritime influence (Hoefler 2010a). Terrain changes and proximity to large waterbodies locally influence the climate. For example, the proximity of Cook Inlet more heavily influences the climate around the project port site than the vicinity of the mine site. Portions of the analysis area that are at higher elevation are likely to experience colder temperatures and differences in precipitation patterns relative to those areas at lower elevations. Summer temperatures are moderated by the open waters of Iliamna Lake, the Bering Sea, and Cook Inlet. During winter, ice forms on these open waters, resulting in a more continental temperature pattern. Overall, the weather systems arrive from the west and southwest, bringing cool to cold air that is often saturated with moisture. These systems result in frequent clouds, rain, and snow, with possible thunderstorm activity during the warm season.

Meteorological monitoring was conducted at the mine site and Cook Inlet by Hoefler (2010a, b) and SLR (2013a, 2015a). The Cook Inlet monitor (Port Site 1) is about 30 miles northeast of the Amakdedori port site. Table 3.20-5 presents monthly and annual averages for mean temperature, mean wind speed, and total precipitation for the mine site (Pebble Site 1) and Cook Inlet (Port Site 1) monitors, respectively. The Port Site 1 monitor has recorded slightly warmer average monthly temperatures than the Pebble Site 1 monitor (Table 3.20-5). At the Port Site 1 monitor, wind is generally from the north and northeast due to local terrain influences (Hoefler 2010b). At the Pebble Site 1 monitor, the wind is bimodal, generally from the northwest or the southeast (Hoefler 2010a). The differences in observations are likely due the influence of Cook Inlet and elevation of the monitors.

Monthly climate averages for Iliamna Airport are listed in Table 3.20-6. These averages are from 30 years of data collection and represent long-term averages compared to the Pebble Site 1 monitor, which collected data for 7 years. The 30-year record minimizes the naturally occurring year-to-year variability that can bias a shorter-term record. Overall, the Iliamna Airport has colder temperatures during the winter, and warmer temperatures during the summer, with less annual precipitation than the Pebble Site 1 and Port Site 1 monitoring sites.

Estimated predicted future temperature and precipitation values for Iliamna, Alaska are presented in Table 3.20-7**.** These data were obtained from the Scenarios Network for Alaska and Arctic Planning (SNAP) for scenario A1B (SNAP 2018). For the period from 2040-2049, the annual average temperatures are projected to increase relative to the Pebble Site 1 (Table 3.20-5) and Iliamna Airport (Table 3.20-6). Relative to the Iliamna Airport, all months, except July, are projected to have an increase in precipitation. An increase in temperatures, coupled with a decrease in precipitation during the summer months, could lead to an increase in drought and wildfire frequency, as well as more fires due to a longer fire season and higher temperatures that allow for drying out of vegetation (Peterson et al. 2014). Total areas burned by fire are projected to triple by the end of the century under some climate projections (ADEC 2010). An increase in wildfires would result in an increase of particulate matter emissions relative to the background conditions. Windblown dust and particulate matter could also increase from a reduction in vegetative cover that could result from plant stress caused by higher temperatures and lower precipitation.

Table 3.20-5: Monthly Climate Summary for Pebble Site 1 and Port Site 1 Monitors

Monitor	Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Pebble Site 1 Monitor, 2005-2012[1]	Average Temperature (°F)	24.9	27.5	26.5	30.8	34.2	36.1	37.8	36.9	35.5	31.3	26.3	26.8	31.2
	Average Wind Speed (mph)	18.7	21.3	18.5	17.5	15.9	14.8	14.7	14.3	15.8	16.9	20.3	20.9	17.5
	Average Total Precipitation (inches)	2.4	3.5	2.0	1.7	1.4	3.3	5.8	4.2	5.0	3.9	2.6	4.0	39.9
Port Site 1 Monitor, 2008-2012[2]	Average Temperature (°F)	28.8	30.1	30.2	33.1	35.8	37.4	38.5	38.8	37.3	34.3	30.6	30.0	33.7
	Average Wind Speed (mph)	12.3	12.9	12.2	10.0	8.3	6.8	8.0	7.1	9.6	10.2	12.1	13.5	10.2
	Average Total Precipitation (inches)	4.5	4.4	1.5	4.9	3.7	4.3	9.5	5.5	6.6	6.4	3.2	4.0	58.5

Notes:
[1]Period of record January 2005 through 2012; elevation 1,560 feet above mean sea level (amsl). Source: Hoefler 2010a; SLR 2015a
[2]Period of record: August 2008 through 2012; elevation: 50 feet amsl. Source: Hoefler 2010b; SLR 2013a
°F = degrees Fahrenheit
mph = miles per hour

Table 3.20-6: Monthly Climate Summary, Iliamna Airport, 1981-2010[1]

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Maximum Temperature (°F)	24.6	26.3	30.7	39.8	51.6	59.4	62.5	61.1	53.9	40.8	29.3	26.9	42.4
Average Minimum Temperature (°F)	12.8	13.4	16.7	25.9	36.6	44.2	49.2	48.4	42.1	29.6	18.1	15.0	29.4
Average Mean Temperature (°F)	18.7	19.9	23.7	32.9	44.1	51.8	55.9	54.8	48.0	35.2	23.7	21.0	35.9
Average Total Precipitation (inches)	1.35	1.09	0.91	0.92	1.09	1.26	2.61	4.04	4.46	3.30	2.08	1.58	24.69
Average Total Snow Fall (inches)[2]	10.8	9.5	9.8	5.3	1.0	0.0	0.0	0.0	0.0	2.5	8.5	11.8	59.2
Average Snow Depth (inches)[2]	8	10	11	7	0	0	0	0	0	0	2	5	4

Notes:
[1]Period of Record 1981-2010; elevation: 19 feet above mean sea level (amsl)
[2]Snow fall and snow depth are for period of record: February 1, 1920 to June 8, 2016
°F = degrees Fahrenheit
Source: WRCC 2018

Table 3.20-7: SNAP Data for Iliamna, 2040-2049[1]

Site	Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Iliamna	Average Mean Temperature (°F)	24	25	30	38	47	53	58	58	51	39	31	24	40
	Average Total Precipitation (inches)	2	1	1	1	1	2	3	5	5	4	3	2	26

Notes:
[1]Numbers are calculated using SNAP data from A1B scenario (i.e., balance across all sources) and the 2040-2049 decade
°F = degrees Fahrenheit
Source: SNAP 2018

3.21 FOOD AND FIBER PRODUCTION

The Farmland Protection Policy Act of 1994 was enacted to reduce the amount of highly productive farmland being converted to non-agricultural uses as a result of various federal programs. Farmland includes prime farmland, unique farmland, and land of statewide or local importance. Prime farmland is defined as available land that has the best combination of physical and chemical characteristics for producing food, feed, forage, fiber, and oilseed crops. Unique farmland is land other than prime farmland used for the production of specific high value food and fiber crops. Farmland subject to the requirements does not have to be currently used for cropland. It can be forest land, pastureland, cropland, or other land, but not water or urban built-up land. The United States Army Corps of Engineers (USACE) is required to assess the potential impacts on farmland during the National Environmental Policy Act (NEPA) review process, under a public interest review of food and fiber. While there may be small outdoor or indoor garden projects in individual communities, there are no state- or federally designated prime or unique farmlands in the project area.

In most of the US, agriculture provides food, natural fibers, biofuels, and other products to American consumers; however, in southwest Alaska, subsistence is the most important source of non-imported food and raw materials (see Section 3.9, Subsistence).

3.22 WETLANDS AND OTHER WATERS/SPECIAL AQUATIC SITES

The affected environment for wetlands and other waters and special aquatic sites includes vegetated wetlands, ponds, lakes, streams, rivers, and marine and estuarine waters that may be directly or indirectly affected from construction or operation of project alternatives and components.

Wetlands in the environmental impact statement (EIS) analysis area are predominantly peatlands, where black spruce (*Picea mariana*) woodlands, low ericaceous and shrub birch (*Betula nana*) scrub, and tussock-forming sedges or grasses are common (Three Parameters Plus 2008). Wet meadows develop in upper drainages, while shrub wetlands become more common along riparian corridors in valley bottoms. In lower drainages, floodplains develop as complex mosaics of forest, shrubland, and aquatic bed in flood channels, bars, and abandoned channels. Saltwater marshes and mudflats are found in protected areas along the coast (HDR 2019a, i).

Other waters in the analysis area include the estuarine and marine waters of Cook Inlet and the unvegetated portions of inland lakes, ponds, rivers, and streams. Cook Inlet fills a shallow marine basin; its waters carry a high load of sediment delivered by large glacial rivers at the head of Knik and Turnagain Arms. Iliamna Lake is the largest lake in Alaska; and although flanked by lowlands, its waters are derived in part from alpine glaciers. Smaller lakes and abundant ponds perch on bedrock or are fed by surrounding wetlands. Although no ephemeral streams have been documented in the analysis area, intermittent streams occupy topographic headwaters and feed clear-running perennial streams and rivers that fall to either Bristol Bay or Cook Inlet.

The special aquatic sites considered here possess unique ecological characteristics of productivity, habitat, wildlife protection, or other important and easily disrupted values. Those occurring in the analysis area include wetlands, mudflats, vegetated shallows, and riffle and pool complexes.

3.22.1 Regulatory Framework

Section 404 of the Clean Water Act (CWA) (33 United States Code [USC] 1344) and Section 10 of the Rivers and Harbors Act (RHA) (33 USC 403) establish programs to regulate dredging and the discharge of dredged or fill material into waters of the United States (WOUS), including wetlands. Section 10 also regulates work and/or structures placed in and over navigable waters of the US (NWUS). Activities in WOUS regulated under this program include fills for development, water resource projects, infrastructure development, and conversion or manipulation of wetlands. For the purposes of this project, all wetlands, streams, rivers, lakes, ponds, tidal waters, and other aquatic resources that would be affected by the activities requiring Department of the Army authorization are treated as waters of the US.

The premise of these programs is that no discharge of dredged or fill material may be permitted if a practicable alternative exists that is less damaging to the aquatic environment, or if the nation's waters would be significantly degraded. Towards this end, mitigation measures to avoid, minimize, rectify, reduce, or compensate for resource losses is considered throughout the application process. Mitigation requirements generally fall into three categories: project modifications to minimize adverse project impacts; mitigation required to satisfy legal requirements; and mitigation required as a result of the public interest review process.

Applicants must demonstrate that steps have been taken to avoid impacts to wetlands and other waters; that potential impacts have been minimized; and that compensation will be provided for remaining unavoidable impacts. Pursuant to 33 Code of Federal Regulations [CFR] Part 320.4(r)(2), all compensatory mitigation required by the US Army Corps of Engineers (USACE) will be for significant resource losses that are specifically identifiable, reasonably likely to occur, and of importance to the human or aquatic environment. In addition, mitigation will be directly related to the impacts of the proposal, appropriate to the scope and degree of those impacts, and reasonably enforceable (see Chapter 5, Mitigation). Pebble Limited Partnership (PLP) has prepared a draft Compensatory Mitigation Plan (CMP) (PLP 2020-RFI 056a) outlining their proposed approach for compensatory mitigation to offset environmental losses resulting from unavoidable impacts to aquatic resources (see Appendix M2.0, Applicant's Draft Compensatory Mitigation Plan).

NWUS overlap with WOUS in that they include the oceans and navigable coastal and inland waters, lakes, rivers, and streams. USACE jurisdiction over NWUS extends shoreward to the mean high-water line. USACE maintains a list of non-tidal, navigable waters in Alaska that have been determined to be NWUS by the district engineer (USACE 2018b). NWUS in the analysis area that are regulated under Section 10 of the RHA include Iliamna Lake and Cook Inlet. Navigable waters of the state are addressed in Section 3.12, Transportation and Navigation. The Newhalen and Gibraltar rivers are also considered navigable by the US Coast Guard (USCG) (see Section 3.12, Transportation and Navigation, for further discussion of navigable waters).

Wetlands are a subset of WOUS and are defined as areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions (33 CFR Part 328.3[b]). Note this definition of wetlands does not include unvegetated waterbodies such as streams and ponds. All wetlands and waterbodies in the study area were assumed to constitute a "significant nexus" to a downstream Traditionally Navigable Water and would be regulated by USACE (HDR 2019i).

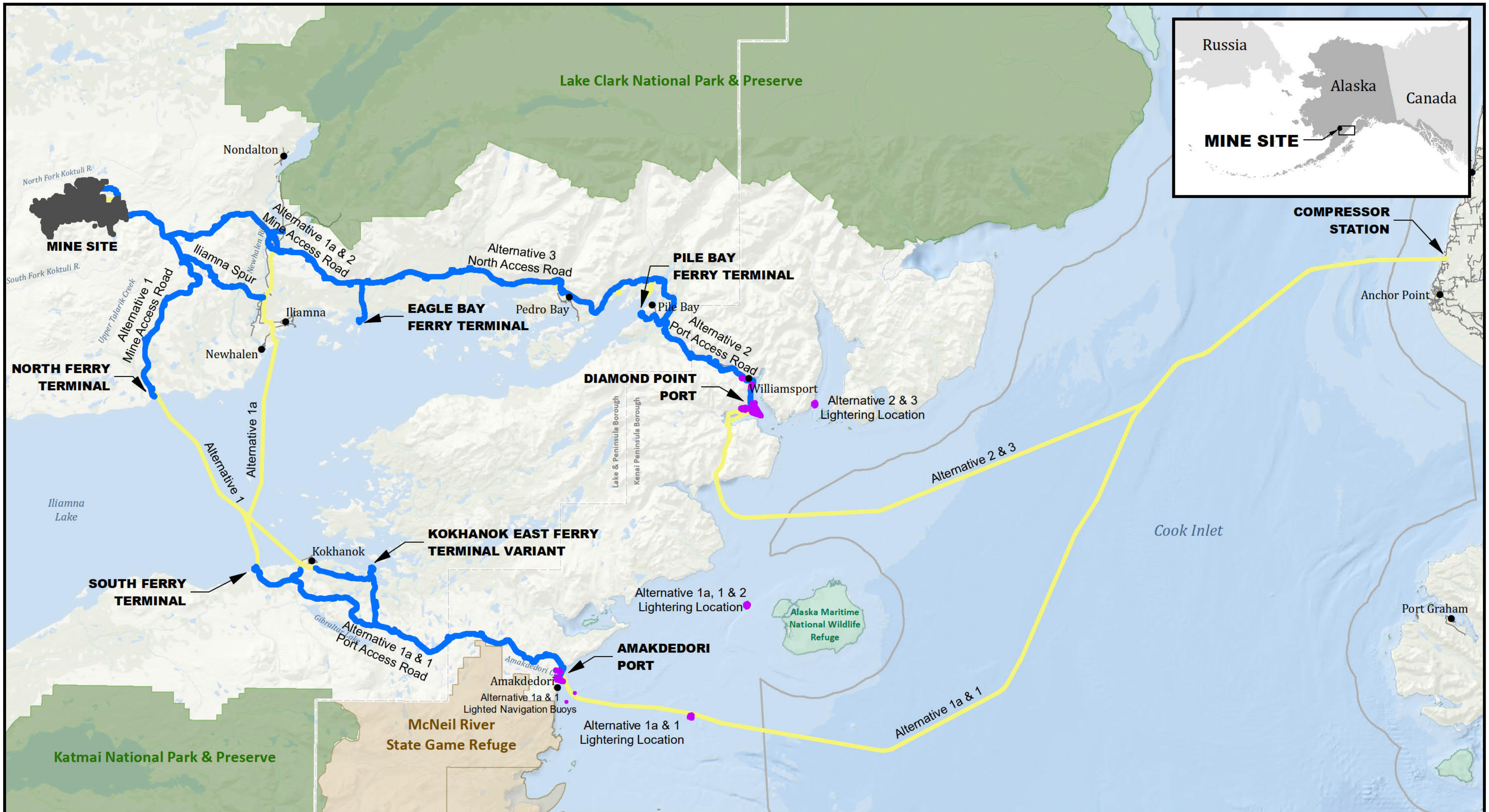
In accordance with national (USACE 1987) and regional (USACE 2007) guidance on wetland delineation, wetlands satisfy the following diagnostic criteria: 1) a prevalence of vegetation typically adapted for life in saturated soil conditions; 2) soils that are formed under conditions of saturation, flooding, or ponding long enough during the growing season to develop anaerobic conditions; and 3) inundation or saturation of the soil during the growing season. "Other waters" is a term often used to describe those jurisdictional waters such as rivers, streams, lakes, and other aquatic sites that do not meet the definition of wetlands.

Special aquatic sites are a subset of WOUS, and are defined as large or small areas possessing special ecological characteristics of productivity, habitat, wildlife protection, or other important and easily disrupted ecological values (40 CFR Part 230.3). Special aquatic sites include wetlands, sanctuaries and refuges, mudflats, vegetated shallows, coral reefs, and riffle and pool complexes.

3.22.2 EIS Analysis Area

The EIS analysis area includes the area potentially affected by direct and indirect impacts from project construction and operations. The analysis area collectively includes areas for all project components (mine site, transportation corridor, ports, and natural gas pipeline) under each alternative, including their variant(s); see Chapter 2, Alternatives, for an explanation and maps of alternatives, variants, and project components. The analysis area for wetlands and other waters is presented in Figure 3.22-1.

Mine Site—The mine site analysis area includes the direct disturbance footprint extended by the maximum extent of areas of indirect disturbance. Areas of indirect disturbance are: the areas of aquatic resources identified as fragmented; a 330-foot buffer around the direct disturbance footprint to account for the potential deposition of fugitive dust; and the maximum geographic extent of all modeled groundwater drawdown scenarios (i.e., end of mining post-closure, and baseline, high-, and low-permeability scenarios) to account for impacts from dewatering and changes to surface flows.



Sources: PLP 2020-RFI-168;
PLP 2019-RFI153; ADNR

US Army Corps
of Engineers®

5 0 5 10

Miles

Analysis Areas
- Mine Site
- Transportation
- Port
- Natural Gas Pipeline

Other Features
- Local Roads
- Borough Boundary
- Three Nautical Mile Line

- National Park
- National Wildlife Refuge
- State Game Refuge/Sanctuary

ANALYSIS AREA FOR WETLANDS AND OTHER WATERS

PEBBLE PROJECT EIS

FIGURE 3.22-1

Transportation Corridor and Ports—The transportation corridor and ports analysis areas include the direct disturbance footprints of access roads, material sites, ferry terminals, and port facilities extended by 330 feet to account for the indirect impacts of fugitive dust deposition. Although the direct disturbance footprints are included for the pile-supported and caisson dock designs (both of which have concrete decking), lightering areas, and mooring buoys, these features are not buffered, because they are not expected to be sources of fugitive dust.

Natural Gas Pipeline—The natural gas pipeline corridor analysis area includes the stand-alone (pipeline-only) sections where the pipeline is not co-located with the transportation corridor. These sections of the natural gas pipeline have a maximum impact width of 91 feet through Iliamna Lake, 101 to 183 feet through Cook Inlet, and 150 feet through overland areas. The overland analysis area includes the direct disturbance footprints for access roads and material sites buffered by a 330-foot zone to account for dust impacts.

3.22.3 Analysis Methodology

3.22.3.1 Wetland and Other Waters Mapping and Classification

Field data collection—Wetland and vegetation surveys were conducted over multiple field seasons. Work conducted from 2004 to 2008 and in 2013 and 2017 is summarized in Chapter 14 and Chapter 39 of the Environmental Baseline Document (EBD) (Three Parameters Plus and HDR 2011b; HDR and Three Parameters Plus 2011b), and the preliminary jurisdiction determination (PJD) reports (HDR 2019a, i). Supplemental wetland data collected at the mine site in 2018 for Alternative 2—North Road and Ferry with Downstream Dams and Alternative 3—North Road Only, as well as the Kokhanok East variant of Alternative 1 in 2019, are provided in Requests for Information (RFIs) PLP 2018-RFI 082, PLP 2018-085, and PLP 2019-RFI 116.

Field data were collected to satisfy a variety of project needs, and are represented by five different collection types: jurisdictional determination plots, functional assessment plots, shrub height plots, representative photo points, and waterbodies and stream crossing photo points. A total of 1,122 jurisdictional determination plots, which included detailed descriptions of vegetation, hydrology, and soils, were collected for the analysis area. Functional assessment data were collected at sites with primary indicators for wetland vegetation, hydrology, and soils. Shrub height forms documenting structurally dominant vegetation and an abbreviated suite of hydrology and soils variables were completed to locate future jurisdictional determination plots, as well as to ground-truth shrub types in support of digital mapping. Representative photo points were taken to document representative wetland and upland vegetation, also in support of digital mapping. Waterbody and stream crossing photo points were collected to document waterbody characteristics, pH, electrical conductivity, and adjacent vegetation type.

Wetland determinations followed guidance from the USACE. Determinations from 2004 through 2008 were based on the 1987 Wetland Delineation Manual (USACE 1987); determinations after 2013 were based on the 1987 Manual, in conjunction with the 2007 Alaska Regional Supplement (USACE 2007b). Where differences in the two documents occur, the Regional Supplement takes precedence over the USACE 1987 Manual.

Digital mapping—The identification and digital delineation of wetland and deepwater habitat from aerial photography referenced existing geospatial and field data, and required interpretation of photographic signature, hydrologic connectivity and landscape position. Wetland boundaries were digitized on aerial photography at a scale between 1:1,200 and 1:1,500; the digitization of waterbodies used aerial photography scaled at 1:400. An average minimum mapping unit of 0.05 acre was used.

Each mapped polygon was attributed by a vegetation type and wetland status. Vegetation type was assigned in accordance with Alaska Vegetation Classification (Viereck et al. 1992) and was informed by landcover mapping completed by Wibbenmeyer and others (1982); see Section 3.26, Vegetation, for discussion of vegetation. Wetland status was assigned to each polygon following review of field data, site photos, similar sites, and based on criteria put forth in the wetland delineation manual (USACE 1987, 2007b).

Polygons judged to represent wetland or deepwater habitat were further classified in accordance with the National Wetland Inventory (NWI) system. The NWI classification system was proposed by Cowardin and others (1979), formalized by the Federal Geographic Data Committee (FGDC 2013), and is now administered as the national standard for wetland mapping in the US by the US Fish and Wildlife Service (USFWS). Under this classification scheme, wetlands and deepwater habitats are grouped into systems (Marine, Estuarine, Riverine, Lacustrine, and Palustrine) based on shared hydrologic, geomorphologic, chemical, or biological factors; and further divided into classes and subclasses based on water regime, substrate, and vegetation.

Field-verified mapping of wetlands and other waters was completed for the entirety of the EIS analysis area since publication of the Draft EIS (DEIS). The greater resolution and coverage gained through this mapping has eliminated wetlands data gaps, allowing finer-scale mapping of smaller streams and wetland-upland mosaics. As a result of the identification of additional small-scale watercourses, stream miles increased in the direct and indirect impact analysis areas. Conversely, wetlands acreages generally decreased within the direct and indirect impact analysis areas through applying finer-scale mapping because wetland-upland mosaics that were previously assumed to represent 100 percent wetland habitat were classified into discrete areas of wetland and upland, thereby decreasing the overall area of wetland habitat.

A hydrogeomorphic (HGM) class (Brinson 1993) was attributed to each wetland and deepwater polygon, based on field data, topography, and interpretation of site hydrology from landscape position. When polygons were designated as both wetlands and uplands (i.e., a mosaic), the HGM designation applied only to the wetland portion of the mapped polygon; see the Inference of Wetland Functions and Values section below.

Because NWI and vegetation types are numerous, these types were generalized to the broader classes of NWI Group and Project Vegetation Type, respectively. NWI groups included the NWI codes as presented in Table 3.22-1; the generalization of project vegetation types to structural vegetation types is presented in Appendix K3.26, Vegetation.

Other waters—Field-verified stream mapping was completed using the same methods as above; however, these data were collected as polygons (HDR 2019i), and therefore did not include centerlines. Using the Geographic Information System (GIS) polygon-to-centerline tool, centerlines were created for each polygon and classified by stream type (e.g., lower perennial, upper perennial and intermittent), and further by their relationship to the system (e.g., main channel, side channel or minor tributary, or disconnected). For description of the affected environment, both the area and length of streams are presented; total areas for "other waters" includes the areas of streams.

Descriptions of wetlands and other waters provided herein are largely based on information provided in Chapters 14 and 39 of EBD (Three Parameters Plus and HDR 2011a; HDR and Three Parameters Plus 2011b), as well as more recent information provided in the PJD reports (HDR 2019a, i) and the associated GIS database, which reflects changes in the project area since publication of the EBD. The last update to the GIS database was in May 2020. All calculations for areas are rounded to the nearest whole acre, or nearest whole percent; calculations for lengths are rounded to the nearest tenth of a mile. Apparent minor inconsistencies in sums are the result of rounding. The USACE PJD determination letter is provided as Appendix J; a wetlands mapbook of field-verified wetlands mapping (along with impact areas, discussed in Section 4.22, Wetlands and Other Waters/Special Aquatic Sites) is included as Appendix K4.22.

Table 3.22-1: Generalization of NWI Codes to NWI Groups

NWI Group	NWI Codes Included	NWI Systems Represented in the Analysis Area				
		Marine	Estuarine	Riverine	Lacustrine	Palustrine
Aquatic Bed	Any freshwater system including the “Aquatic Bed” class				X	X
Herbaceous	Any freshwater system including the “Emergent” class					X
Broad-Leaved Deciduous Shrubs	Any system including the “Scrub-Shrub” class and “Broad-Leaved Deciduous” subclass					X
Evergreen Shrubs	Any system including the “Scrub-Shrub” class and “Broad-Leaved Evergreen” or “Needle-Leaved Evergreen” subclasses					X
Deciduous Forest	Any system including the “Forested”' class and “Broad-Leaved Deciduous” subclass					X
Evergreen Forest	Any system including the “Forested” class and “Needle-Leaved Evergreen” subclass					X
Estuarine (Intertidal)	Intertidal subsystems of the “Estuarine” system		X			
Estuarine (Subtidal)	Subtidal subsystems of the “Estuarine” system		X			
Lakes	All allowable[1] classes of the “Lacustrine” system				X	
Marine (Intertidal)	Intertidal subsystems of the “Marine” system	X				
Marine (Subtidal)	Subtidal subsystems of the “Marine” system	X				
Ponds	Unvegetated classes of the “Palustrine” system					X
Streams (Intermittent)	Intermittent subclass of the “Riverine” system			X		
Streams (Perennial)	Perennial subclasses of the “Riverine” system			X		
Streams (Tidal)	Tidal subclass of the “Riverine” system			X		

Notes

[1] Allowable per the NWI Water Regime Restriction Table (NWI 2016)

NWI = National Wetland Inventory

3.22.3.2 Inference of Wetland and Other Waters Functions and Values

The HGM classification system was developed by Brinson (1993) as a conceptual framework for the assessment of physical, chemical, and biological functions of wetlands. This approach groups wetlands into categories based on the wetland's geomorphic setting, water source, and hydrodynamics, and recognizes riverine, slope, depressional, flat, lacustrine, and coastal fringe wetland types; the lacustrine, riverine channel, and marine water types are specific to the Pebble Project and were used to attribute other waters. These project-specific HGM classes are equivalent to the NWI subsystems of lacustrine-limnetic and unvegetated classes of lacustrine-littoral, unvegetated classes of the riverine system regardless of subsystem, and marine-subtidal and unvegetated classes of marine-intertidal, respectively.

When used in combination with the NWI classification system, the HGM class can give greater resolution to the ecological processes of wetlands with shared vegetation structure. Because an accepted methodology for wetland functional assessment is not available for this region of Alaska, a formal wetland functional assessment has not been completed; a functional assessment is not required for an EIS. In the absence of a formal assessment, wetland functions in the analysis area can be discussed qualitatively from the intersection of NWI classification and HGM class.

3.22.4 Wetlands and Other Waters

Wetlands—Wetlands occupy approximately 10 percent of the analysis area and are represented by vegetated palustrine and estuarine habitat. Palustrine is the dominant wetland system; estuarine wetlands represent less than 1 percent of analysis area wetlands. Palustrine wetlands may be further subdivided by physiognomic class (e.g., forested, scrub-shrub, moss/lichen, or emergent).

Palustrine scrub-shrub wetlands are the dominant NWI class in the analysis area. These include the "broad-leaved deciduous shrub" wetland type, characterized by broad-leaved deciduous shrubs such as dwarf birch, and willows (*Salix fuscescens*, *S. pulchra*); broad-leaved evergreen shrubs such as sweetgale (*Myrica gale*), Labrador tea (*Ledum palustre, L. groenlandicum*), bog rosemary (*Andromeda polifolia*), black crowberry (*Empetrum nigrum*), lingonberry (*Vaccinium vitis-idaea*), and bog blueberry (*V. uliginosum*). Also included under the palustrine scrub-shrub wetland class is the "evergreen shrub" wetland type, which is characterized by needle-leaved evergreen scrub such as stunted black spruce. Although palustrine moss/lichen wetlands are not represented in the analysis area, peatmosses in the *Sphagnum* genus have nearly constant presence in analysis area bogs.

Palustrine emergent wetlands make up the second-most dominant NWI class in the analysis area. These include the "herbaceous" wetland type and are characterized by persistent, herbaceous species adapted to a wide range of saturation or non-permanent flooding. Dominant graminoids include the sedges (*Carex aquatilis*, *C. lyngbyei*), tall cottongrass (*Eriophorum angustifolium*), and bluejoint grass (*Calamagrostis canadensis*); dominant forbs are field horsetail (*Equisetum arvense*), purple marshlocks (*Comarum palustre*), and cloudberry (*Rubus chamaemorus*).

Palustrine forested wetlands occur in a very small portion of the analysis area. These are primarily the "deciduous forest" wetland type characterized by broad-leaved deciduous tree species and developing in valley bottoms and along toeslopes. Dominant tree species include balsam poplar (*Populus balsamifera* ssp*. balsamifera*) and Kenai birch (*B. papyrifera* var. *kenaica*); dominant shrub species include willows (*Salix pulchra*); and less frequently, alders (*Alnus incana* ssp. *tenuifolia, A. viridis* ssp. *sinuata*). Also included in the palustrine forested wetland class is the "evergreen forest" wetland type characterized by needle-leaved evergreen trees species such as black spruce and developing on flats and in depressions.

Estuarine emergent wetlands are equivalent to the "estuarine (intertidal)" wetland type and develop along protected shores of Cook Inlet where fine sediment can accumulate. These herbaceous communities are tidally influenced and characterized by species adapted to living in saline environments. The dominant species include circumpolar reedgrass (*Calamagrostis deschampsioides*), Lyngbye's sedge, largeflower speargrass (*Poa eminens*), and the forbs Arctic daisy (*Chrysanthemum arcticum*), and Pacific silverweed (*Argentina egedii* ssp. *egedii*).

Other Waters—Other waters, as used in this section, include all non-wetland waters and occupy approximately 19 percent of the analysis area. Most of these areas are deepwater habitats characterized by permanent water and non-soil substrates. In the analysis area, these include marine and estuarine waters, both subtidal (continuously submerged) and unvegetated intertidal habitats (exposed during low tides), as well as ponds, lakes, rivers, and streams; floating or rooted aquatic herbaceous vegetation may be present.

No ephemeral streams were identified in the analysis area; all non-perennial streams were classified as intermittent (Three Parameters Plus and HDR 2011b). Intermittent streams are differentiated from ephemeral streams based on duration, timing, and sources of flow, which may vary year-to-year. Ephemeral streams flow for brief periods (i.e., hours to a few days) during and immediately after rainfall events, and do not receive groundwater inputs, whereas intermittent streams flow seasonally (i.e., several weeks or more), with inputs from groundwater, snow melt, and rainfall.

In the analysis area, intermittent streams occupy headwater topographic positions, and typically have flow during the spring snowmelt period (May to June), then may go dry or subsurface during July and August until sufficient rainfall begins again in September. Flow then gradually declines during winter as snow accumulates, and streams are typically dry during February to early April (Knight Piésold et al. 2011). The duration of flow in these streams is related to catchment area and characteristics, and to the relative contribution of groundwater to base flows.

Perennial stream habitat may be further divided as either upper perennial, lower perennial, or tidally influenced. Upper perennial streams tend to have higher gradients, faster flows, coarser substrates, and little floodplain development compared to lower perennial and tidally influenced streams (Cowardin et al. 1979). For the purposes of summarizing the affected environment for wetlands and other waters, upper and lower perennial waterways are collectively referred to as "streams (perennial)"; all tidally influenced freshwaters are referred to as "streams (tidal)."

Both Lacustrine and Palustrine aquatic beds occur in the analysis area and are equivalent to the Vegetated Shallow special aquatic site (Section Special Aquatic Sites subsection). These are typically permanently flooded ponds or lakeshores dominated by rooted, aquatic herbaceous species such as pendantgrass (*Arctophila fulva*), common mare's-tail (*Hippuris vulgaris*), greater creeping spearwort (*Ranunculus flammula*), and threadleaf crowfoot (*Ranunculus trichophyllus*).

3.22.5 Regionally Important Wetlands

Although all wetlands are important to the greater function and value of ecosystems and the subsistence cultures they support, EIS scoping comments identified certain wetland types in the analysis area as having specific regional importance. The Regionally Important Wetlands approach is intended, in part, to complement consideration of the Special Aquatic Sites (Section 3.22.6), which represents several non-wetland (i.e., aquatic) types. Regionally important wetlands types provide habitat for culturally important plants and animals, are rare or high-quality, and/or are pristine and/or difficult to replace. Regionally important wetland types and components identified for the analysis area include:

- Riparian wetlands
- Forested wetlands
- Estuarine wetlands
- Fens
- Culturally important wetland plants

Providing habitat for sensitive or regionally important fish, wildlife, birds, or plant species—Many riparian wetlands in the analysis area provide critical habitat functions for ecologically, economically, and culturally important anadromous and resident fish species. Most of these functions are related to contributions from the riparian plant canopy, through inputs of coarse woody debris and nitrogen (from alders); sediment and streambank stabilization; provision of shading and cover; and food chain support. Riverine herbaceous wetlands are also considered regionally important due to their relatively high species richness (ABR 2011a). For calculating impact acres (see Section 4.22, Wetlands and Other Waters/Special Aquatic Sites), jurisdictional wetlands with an HGM class of Riverine are considered regionally important.

Scarce, or rare and high quality, in a given region—Uncommon habitat types are recognized to make disproportionate contributions to regional biodiversity (Williams et al. 2007). Forested wetlands occupy a very small portion of the analysis area but provide important food and cover for wildlife (such as beavers and moose), and woody inputs that are important for fish habitat and stream dynamics. Estuarine wetlands (i.e., tidal marshes) are similarly uncommon in the analysis area and are recognized as an ecosystem of conservation concern in Alaska, largely due to their support of animal communities (Flagstad et al. 2019). For calculating impact acres in Section 4.22, Wetlands and Other Waters/Special Aquatic Sites, jurisdictional wetlands with an NWI group of Deciduous or Evergreen Forest or Estuarine (Intertidal) are considered regionally important.

Undisturbed and difficult or impossible to replace—Although the majority of wetlands in the analysis area are undisturbed, fens are a unique wetland type that rely on groundwater input, take thousands of years to develop, and cannot be easily restored (Weixelman and Cooper 2009). For calculating impact acres in Section 4.22, Wetlands and Other Waters/Special Aquatic Sites, the open willow – low shrub fen vegetation type is considered regionally important. This type may co-occur with regionally important riparian or forested wetlands.

In addition to the ecosystem functions provided by wetlands, certain wetland types and locations are valued by Alaska Natives for their subsistence value (Ellanna and Wheeler 1989; Hall et al. 1994; Jernigan no date). Social, cultural, economic, and valuative components of Alaska Native societies are integrated in hunting, gathering, fishing, and trapping activities, providing for a dynamic adaptive system focused on the use of local resources. In this way, all wetland types are integral to the functioning of subsistence-based economies (Ellanna and Wheeler 1989).

For the purposes of the EIS, culturally important plants were identified from an ethnobotanical study from the Yukon-Kuskokwim region (Jernigan no date). Of the 73 plant species listed, 12 vascular plant species are recognized as obligate wetland species (Lichvar et al. 2016); although not assigned a wetland indicator status, the Sphagnum moss genus (*Sphagnum* spp.) is included due to its high fidelity to wetland conditions (Seppelt et al. 2008). The wetland species identified as culturally important, the wetland community in which they most often occur, and a description of their traditional ethnobotanical uses is below.

Palustrine scrub-shrub wetlands:

- Sweetgale (*Myrica gale*)—has been used by the Inland Dena'ina to externally treat cuts and boils, and for making a tea for tuberculosis.
- Small cranberry (*Vaccinium oxycoccos*)— is used as a food source; berries are eaten plain to treat coughs, colds, sore throat, and mouth sores. The juice can also be squirted in a sore eye.

Palustrine emergent wetlands:

- Water horsetail (*Equisetum fluviatile*)—root nodules taste sweet and are edible; nodules are gathered along with other stored roots and stems from vole nests in the fall.
- Yellow marsh marigold (*Caltha palustris*)—leaves and stem are collected early, before they flower in the summer. They are boiled before eating, changing the water two or three times to leach out toxic chemicals, including protoanemonin.
- Fourleaf mare's-tail (*Hippuris tetraphylla*)—The whole plant (except the roots and submerged stems) is gathered from ponds right after freeze-up by skimming the ice surface with a shovel or rake. Plants can then be put on tarps to dry and store in bags for the winter. Alternatively, the plants may be gathered in the spring from the lakes when the ice is lifting. Freezing makes the plants soft and easier to cook. The plant is not eaten when green in the summer because it is too bitter.
- Common mare's-tail (*Hippuris vulgaris*)—considered another edible species of mare's-tail (see previous).
- Purple marshlocks (*Comarum palustre*)—tea is brewed from the fruit, flowers, and leaves.
- Palla's buttercup (*Ranunculus pallasii*)—young rhizomes can be harvested when they are just sprouting in the spring. They are boiled and eaten in soups; plants are not edible raw.
- Mackenzie's water hemlock (*Cicuta virosa*)—considered very poisonous; contains the toxic polyacetylene cicutoxin, which acts as a convulsant.
- Sedges (*Carex spp.*)—the fleshy stem base of these sedges is harvested from the nests of voles in the fall, then cooked and eaten.
- Lyngebye's sedge (*Carex lyngbyei*)—Elders said the white base of the stem is edible and contains nutrients, including B vitamins. The roots can also be cut up and cooked. Seeds are collected and used like rice, putting them in seal or duck soup. The stems can be dried and braided into mats or used as insoles for fish-skin boots; blades can also be used to make baskets.
- Tall cottongrass (*Eriophorum angustifolium*) and white cottongrass (*E. Scheuchzeri*)—the base of the stem and underground tuber, or "nut," are edible and can be gathered from the plant itself, or in the fall from vole nests; these are eaten raw or cooked. The flowering tops can be put on sores and boils. These plants are also important as an indicator species. For example, cottongrass blooms are said to be plentiful in years when the berries are plentiful.

Palustrine moss/lichen wetlands:

- Sphagnum moss *(Sphagnum spp.)*—In former times, during famines, Sphagnum moss was dried and eaten with rancid seal oil or whatever was on hand. Sphagnum moss was picked and stored to use for scrubbing dishes and cleaning one's hands after eating. In former times, this species was used as diapers and as the wicks of seal oil lamps. They were also soaked with seal oil and aged to close seams on skin kayaks and boats.

3.22.6 Special Aquatic Sites

Special Aquatic Sites—Special aquatic sites are a subset of WOUS that are large or small areas possessing special ecological characteristics of productivity, habitat, wildlife protection, or other important and easily disrupted ecological values (40 CFR Part 230.3). Special aquatic sites include wetlands, sanctuaries and refuges, mudflats, vegetated shallows, coral reefs, and riffle and pool complexes (40 CFR Part 230.41). These sites influence or positively contribute to the overall environmental health of the entire ecosystem, and therefore receive special attention under EPA's Section 404(b)(1) guidelines.

Although no sanctuaries or refuges occur in the project area, several protected areas are nearby. The Alaska Maritime National Wildlife Refuge is managed by the USFWS, and was established to conserve marine mammals, seabirds and other migratory birds, and the marine resources on which they rely. The natural gas pipeline corridor in Cottonwood Bay would be 250 feet from the nearest refuge island, and would pass approximately 7 miles from a portion of the Alaska Maritime National Wildlife Refuge. Refuge islands are within 3,200 feet of Diamond Point and 900 feet from the nearest dredge area. The primary lightering station would be 2,800 feet from the nearest refuge island, and the proposed alternative lightering station would be 2.25 miles from Augustine Island, which is also included in the refuge. The National Estuarine Research Reserve System is a network of 29 coastal sites cooperatively managed by the National Oceanic and Atmospheric Administration and the member state, and designated to protect and study estuarine systems; Kachemak Bay is included in this network as representative of a high-latitude, fjord estuary type. The natural gas pipeline corridor would pass within 4 miles of the boundary of the Research Reserve. The McNeil River State Game Sanctuary and Refuge is managed for the preservation of wildlife habitat and its unique concentration of brown bears. Coral reefs are not present in the analysis area.

Wetlands—As a special aquatic site, wetlands are defined in accordance with 33 CFR Part 328.3[b]. In Alaska, wetlands generally include wet and moist tundra, bogs, fresh and salt marshes, fens and muskegs. Wetland types occurring in the analysis area are described throughout this section.

Mudflats—Mudflats are broad, flat areas along the coast; coastal rivers to the head of tidal influence; and in inland lakes, ponds, and riverine systems. The substrate of mud flats contains organic material and particles smaller in size than sand. They are either unvegetated or vegetated only by algal mats. When mud flats are inundated, wind and wave action may resuspend bottom sediments. Coastal mud flats are exposed at extremely low tides and inundated at high tides with the water table at or near the surface of the substrate. For calculating impact acres in Section 4.22, Wetlands and Other Waters/Special Aquatic Sites, mudflats are defined as any jurisdictional wetland classified in the NWI system as having an unconsolidated shore with mud substrate. This special aquatic site includes estuarine intertidal habitat, described above as a regionally important wetland type.

Vegetated Shallows—Vegetated shallows are permanently inundated areas that under normal circumstances support rooted aquatic vegetation; vegetated shallows may be found in the estuarine, marine, riverine, and lacustrine systems; only palustrine and lacustrine vegetated shallows are documented in the analysis area. The submerged aquatic vegetation characteristic of vegetated shallows provides food and habitat for species, as well as maintaining water quality by absorbing nutrients, trapping sediments, reducing erosion, and producing oxygen. Algal subsidy provides food for a variety of grazing invertebrates, especially crustaceans, which in turn, become prey for numerous species of fish, mammals, and birds.

Although vegetated shallows are not documented in the port analysis areas at Diamond Point or Amakdedori, rocky reefs are present in outlying intertidal to subtidal portions of Iliamna Bay, Cottonwood Bay, Ursus Cove, and Kamishak Bay. These reef habitats support dense macro-algal communities exhibiting strong vertical zonation. Upper intertidal zones are dominated by rockweed (*Fucus distichus*) and the reds (*Mastocarpus* spp., *Mazzaella* spp.) transitioning to red algae, especially red ribbon species (*Palmaria* spp.) and sea sac (*Halosaccion glandiforme)* with depth. The lower intertidal zone is dominated by larger kelps such as *Alaria* and *Saccharina* species. Eelgrass (*Zostera marina*) is found predominantly south of Amakdedori around reefs associated with Nordyke Island and Chenik Head, north of Amakdedori near Contact Point, and in patchy beds in Iliamna and Cottonwood bays (GeoEngineers 2018c).

In the freshwater environment of the analysis area, vegetated shallows are largely associated with pond, lake, and stream margins. In the analysis area, vegetated shallows develop along pond margins at the mine site and along the Iliamna Lake shoreline at all three ferry terminal locations. For calculating impact acres in Section 4.22, Wetlands and Other Waters/Special Aquatic Sites, vegetated shallows are defined as any jurisdictional wetland classified as aquatic bed under the NWI group classification.

Riffle and Pool Complexes—Riffle and pool complexes are most likely to develop in steep- to moderate-gradient sections of streams where the rapid movement of water over a coarse substrate in riffles results in rough flow, a turbulent surface, and high levels of dissolved oxygen in the water. Pools are deeper areas associated with riffles and characterized by a slower stream velocity, smooth surface, and finer substrate. Riffle and pool complexes are particularly valuable habitat for fish and wildlife.

Baseline mapping of streams did not explicitly identify riffle and pool complexes in the analysis area, with the exception of the North Fork Koktuli (NFK) and South Fork Koktuli (SFK) rivers, and Upper Talarik Creek (UTC) near the mine site (R2 et al. 2011a). These streams are low-gradient, meandering watercourses that are bordered by open to closed low-shrub communities, often dominated by willow species. Habitat typing discussed in Section 3.24, Fish Values, indicates that the mainstem NFK (Reaches A through C) below the mine site is dominated by riffle habitat (56 to 65 percent) with few pools (1 to 2 percent). Upstream of the mine site, the NFK (Reach D) is similarly dominated by riffle habitat (46 percent), with increasing frequency of pools (9 percent) due in part to a greater incidence of beaver-dammed pools in its headwaters. The presence of riffle habitat in reaches of the SFK (Reaches A through D) ranges from 27 to 65 percent, with pools relatively rare (2 to 5 percent). Reaches of the UTC (A through F) show a more even ratio of riffle and pool habitat, with percent riffle habitat ranging from 16 to 54, and percent pool habitat ranging from 1 to 22. Although the riffle-to-pool ratio among reaches of the SFK varies with downstream position, reaches of both the NFK and UTC show decreasing presence of pools with downstream position (see Table 3.24-1).

All riverine habitat was characterized by flow regime (lower perennial, upper perennial, and intermittent). Riffle and pool complexes would be expected to occur most frequently in the upper perennial zone where gradients are steeper and stream beds are predominantly gravel or coarser substrates. The area and length of upper perennial stream habitats are used as a proxy for riffle and pool presence. By this definition, the perennial reaches of the NFK, SFK, and UTC shown in Figure 3.24-1 are included as riffle and pool complexes. Stream morphology and associated fish habitat in the analysis area is described in detail in Section 3.24, Fish Values; surface water quality is addressed in Section 3.18, Water and Sediment Quality.

3.22.7 Wetland and Other Waters Functions and Values

Functions can be defined as the processes necessary for the maintenance of an ecosystem, whereas values are associated with society's perception of those ecosystem functions. The value of a wetland is therefore based on human judgment of the worth, merit, quality, or importance attributed to the functions of that wetland (Hall et al. 2003). High-value wetlands often include those providing habitat for threatened or endangered species, regionally scarce or rare and high-quality wetlands in a given region, and undisturbed wetlands whose ecological functions are difficult or impossible to replace within a human lifetime. Because the USACE evaluates environmental, economic, and social concerns before deciding whether to grant a permit, the impact to wetland function and associated values is an important component of their decision process.

Functions and values considered by the regulatory branch for CWA Section 404(b)(1) wetland permits (USACE 2015) include the modification of groundwater recharge and discharge, storm- and floodwater storage, modification of flow and water quality, production and export of organic matter, as well as contribution to the abundance and diversity of wetland flora and fauna. Values ascribed to these functions include opportunities for recreational and subsistence use; aesthetic values relating to an intact viewshed, education, and scientific research, as well as the uniqueness and heritage values of a wetland. Recreational use is considered non-consumptive, whereas subsistence use is considered consumptive and includes hunting, fishing, trapping, and gathering. The following description of HGM classes and associated functions and values (Table 3.22-2 and Table 3.22-3) are modified from Hall and others (2003), Lee and others (1999), and Natural Resources Conservation Service (NRCS) (2008). Although functional overlap among types of wetlands and other waters exists, functions are likely to be performed at different levels and intensities by ecologically distinct wetlands and waters. Similarly, because the identification of wetland values is subjective, all values may be applied to any wetland type; the emphasis (bold "X") given in Table 3.22-3 indicates primary values associated with a given wetland type, and is based on professional judgement. The following section summarizes the functions and values generally associated with recognized classes of wetland hydrogeomorphology and vegetation. This qualitative description does not constitute a formal wetland assessment.

Slope Wetlands are found where there is a discharge of groundwater to the land surface. They typically occur on sloping land where elevation gradients may range from steep hillsides to nearly level terrain. Slope wetlands are usually incapable of depressional storage. Principal water sources are usually groundwater return flow and interflow from surrounding uplands, as well as precipitation. Hydrodynamics are dominated by downslope, unidirectional water flow. Slope wetlands lose water by overland and surface flows and by evapotranspiration.[1] Channels may develop, but they serve only to convey water out of the system.

<u>Slope wetland vegetation</u>—Slope wetlands are the most common HGM wetland type in the analysis area and are predominately represented by the broad-leaved deciduous shrub and herbaceous NWI group types, and to a lesser extent by the open low shrub, wet herbaceous,

[1] The process where water is transferred from the land to the atmosphere by evaporation from the soil and other surfaces.

dwarf shrub, closed tall shrub, open/closed forest, closed low shrub, open tall shrub, and dry to moist herbaceous project vegetation types (listed in decreasing order of representation).

Slope wetlands occur in the analysis area as seeps on footslopes and toeslopes, and as headwaters and drainages in steep to rolling terrain where stream channels have not yet formed. Herbaceous slope wetlands may occur as fens, whereas forested and shrub slope wetlands often develop on toeslopes adjacent to, yet above flood-prone areas of streams.

Table 3.22-2 Summary of Wetland Functions by Hydrogeomorphic Class for Analysis Area

HGM Class	Hydrologic			Biogeochemical					Biotic			
	Storm Surge and Floodwater Storage	Streamflow Modification	Groundwater Recharge	Groundwater Discharge	Organic Carbon Sequestration	Nutrient and Compound Cycling	Detritus Export	Water Quality Modification	Waterfowl Habitat Maintenance	Aquatic Organism Habitat Maintenance	Terrestrial Species Habitat Maintenance	Plant Community Maintenance
Slope		X		X	X	X		X		X	X	X
Depressional			X	X	X	X		X	X	X	X	
Flat				X	X			X		X	X	X
Lacustrine Fringe	X				X	X	X		X	X	X	
Riverine	X	X		X		X	X		X	X	X	X
Coastal Fringe	X				X	X	X		X	X	X	

Note:
HGM = hydrogeomorphic

Table 3.22-3: Summary of Wetland Values by Hydrogeomorphic Class for Analysis Area

HGM Class	Recreation (non-consumptive use)	Subsistence (consumptive use)	Aesthetic	Education/ Scientific	Uniqueness/ Heritage
Slope	**X**	**X**	x	**X**	**X**
Depressional	x	**X**	x	**X**	**X**
Flat	x	**X**	**X**	**X**	**X**
Lacustrine Fringe	**X**	**X**	x	x	**X**
Riverine	**X**	**X**	x	x	X
Coastal Fringe	**X**	**X**	**X**	**X**	**X**

Note:
HGM = hydrogeomorphic

Slope wetland functions—Because slope wetlands develop from the one-way discharge of groundwater and only occur only on surfaces where a change in slope gradient or an aquiclude[2] forces water to the surface, they seldom have any significant surface water. Their maintenance of wildlife habitat is instead provided to resident species that rely on surface saturation (e.g., amphibians). As groundwater is discharged to the surface, it is maintained in temporary storage in the soil, and slowly released as spring flow, which maintains downstream baseflows. Discharges tend to be steady, long-term, and in some cases, can be continuous even through dry years. The deposition of organic material to a saturated surface under anaerobic conditions promotes the accumulation of peat and the sequestration of organic carbon in the soil. Furthermore, groundwater discharge through organic carbon under anaerobic conditions provides good conditions for cycling of dissolved nitrogen (NRCS 2008). The organic matter produced, and nutrients mobilized in slope wetlands contribute to the maintenance of plant, aquatic organism, and terrestrial animal habitat in downstream reaches.

Slope wetland values—As the most common HGM class in the analysis area and broader region, slope wetlands are widely used for subsistence and recreation. Nutrient-rich slope wetlands (i.e., fens) are rare in Alaska; this type of slope wetland is attributed both uniqueness and education value.

Riverine Wetlands occur in association with active floodplains, riparian corridors, and stream channels. The distinguishing characteristic of riverine wetlands is that they are flooded by overbank flow from the stream or river at least every other year; perennial flow in the channel is not a requirement. Dominant water sources are often overbank flow from the channel or subsurface hydraulic connections between the channel and wetlands. Additional sources may include groundwater discharge from shallow aquifers, overland flow from adjacent uplands, tributary inflow, and precipitation. Riverine wetlands lose surface water by flow returning to the channel after flooding, and overland flow to the channel during precipitation events. They lose subsurface water by discharge to the channel, movement to deeper groundwater, and evapotranspiration.

Riverine wetland vegetation—Riverine wetlands are the second most common HGM wetland type in the analysis area and are predominately represented by the broad-leaved deciduous shrub and herbaceous NWI group types—and to a lesser extent—the open low shrub, wet herbaceous, closed and open tall shrub, dry to moist herbaceous, and open/closed forest project vegetation types (listed in decreasing order of representation). Riverine wetlands in the analysis area occur primarily as narrow riparian corridors along higher-gradient streams, and occasionally as broad floodplains along lower perennial streams. At their headwaters, Riverine wetlands are often replaced by slope or depressional wetlands where the channel morphology may disappear. They may intergrade with poorly-drained flats or uplands.

Riverine wetland functions—Riverine wetlands provide dynamic floodwater storage, which affects downstream peak discharges. This function is related to the stream's ability to move water between the channel and the adjacent floodplain. In high-functioning riparian wetlands (i.e., not degraded), floodplain storage capacity is related to microtopographic features and vegetative structure. Where floodplain storage capacity is high, riparian wetlands function to maintain downstream base flows. Riverine wetlands provide a high level of sediment cycling due to alternating accretion and scour. Surface flooding provides the water source for maintenance of surface ponding in macrotopographic features. The maintenance of plant and wildlife communities also relies heavily on the system's hydrograph and sediment dynamics. Dominant woody species are either adventitiously rooting (e.g., willows) and propagated by stems and branches carried by high flow; or grow from seeds dispersed on fresh deposits of sediment (e.g., cottonwoods). Fresh

[2] An impermeable barrier to the flow of water.

stands are initiated during high flow events, and the presence of multi-age stands is indicative of a system that maintains regular flood frequencies. Although fish species often depend on the maintenance of stream processes provided by the active channel, other species rely on the opportunities for off-channel feeding, rearing, and refugia provided by access to the floodplain during high flow. The presence of beaver can further enhance plant and wildlife habitat by increasing the types and abundance of wetland habitat; specifically, snags and downed wood for wildlife, cold-water refugia for fish, and different age classes of vegetation. Waterfowl rely on surface water in riverine systems, and other aquatic and terrestrial animals move readily among riverine landscape elements (NRCS 2008).

<u>Riverine wetland values</u>—Rivers and their associated wetlands are highly valued by residents of and visitors to the Bristol Bay region. In a largely roadless area, rivers provide transportation and critical habitat for subsistence and commercial resources. Therefore, rivers and riverine wetlands are often the focal point of communities with high recreational, economic, subsistence, and heritage value.

Flats Wetlands occur in topographically flat or very gently sloping areas that are hydrologically isolated from surrounding ground or surface water; they can be underlain by mineral or organic soil. Both types develop on interfluves, extensive relic lake bottoms, or large, inactive floodplain terraces. Different from mineral soil flats, organic soil flats develop only in climatic zones where precipitation is well in excess of evapotranspiration, thereby allowing the accretion of organic matter. Through the accumulation of peat, mineral soil flats and depressional wetlands can transition to organic soil flat wetlands. For both mineral and organic types, water source is dominated by precipitation; therefore, these systems are relatively nutrient-poor. Different from slope wetlands, flats wetlands receive no inputs of groundwater. Water loss is by evaporation, overland flow, and seepage to underlying groundwater.

<u>Flats wetland vegetation</u>—Flats wetlands are the third most common HGM wetland class in the analysis area and are predominately represented by the broad-leaved deciduous shrub and herbaceous NWI groups, and the wet herbaceous, open low shrub and open/closed forest project vegetation types. Both mineral and organic soil flats are found in the analysis area; however, they were not differentiated in the field, and are therefore treated collectively as "flats wetlands." In the analysis area, flats wetlands develop on broad ridgetops, glacial outwash terraces, and remnant glacial lake beds. They may transition to slope wetlands at topographic breaks associated with groundwater discharge.

<u>Flats wetland functions</u>—Because no landscape is truly flat, shallow ponding in microtopographic lows of mineral flat wetlands provide some maintenance of waterfowl habitat. These depressions are shallow, with ephemeral to temporary surface water; but can provide ice-free water and wetland habitat earlier than deeper-depression wetlands. Maintenance of the plant community is often codependent with surface saturation, because together, surface microtopography and vegetation community structure can be an important mechanism for the storage and infiltration of water. Flats wetlands may provide critical amphibian breeding, egg-laying, and larval/juvenile habitat (NRCS 2008).

Peat aggradation in organic flat wetlands eventually creates a domed deposit so that surface and groundwater gradients move water to adjacent landscapes at the rate of precipitation. Such ombrotrophic peatlands are nutrient-poor and acidic, which supports the growth of characteristic plant communities. Extensive peat deposition acts also to sequester carbon and store water; the slow release of this water contributes to the maintenance of downstream baseflows. Due to the lack of open water, organic flat wetlands do not typically support waterfowl, but can provide cover and plant and invertebrate food sources for wildlife. Where ambient moisture is high, surface saturation is maintained; consequently, surface runoff can be high. However, the dense vegetation and flat slopes lessen the effect relative to other wetland systems. Organic wetland flats have less potential for cycling of nutrients and compounds due to the lack of groundwater inputs (NRCS 2008).

Flats wetlands values—Flats wetlands provide habitat for prey species, and therefore have hunting value. Expansive wetland flats can be a defining characteristic of the landscape with aesthetic value. The considerable sequestration of carbon in large organic flats wetlands provides opportunity for scientific research, especially related to climate change.

Depressional Wetlands occur in topographic depressions on a variety of geomorphic surfaces. Dominant water sources are precipitation, groundwater discharge, and surface flow and interflow from adjacent uplands. The direction of flow is normally from the surrounding uplands towards the center of the depression, which allows for the accumulation of surface water. Depressional wetlands may have any combination of inlets and outlets; or lack them completely. Dominant hydrodynamics are vertical fluctuations, primarily seasonal. Depressional wetlands may lose water through intermittent or perennial drainage from an outlet, by evapotranspiration, and if they are not receiving groundwater discharge, may slowly contribute to groundwater.

Depressional wetland vegetation—Depressional wetlands are the fourth most common HGM wetland type in the analysis area, and are predominantly represented by the herbaceous and broad-leaved deciduous shrub NWI groups and the wet herbaceous and open low shrub project vegetation types. In the analysis area, depressional wetlands occur as abandoned river features on terraces (e.g., oxbows) above active floodplains, or as kettles on moraine landforms. Depressional wetlands are often embedded in other HGM wetland classes.

Depressional wetland functions—Depressional wetlands may function to provide groundwater recharge or discharge. Recharge depressions receive most of their water as surface runoff and have a soil substrate with low-conductivity soils capable of ponding water. Ponded water provides waterfowl habitat, as well as other wildlife habitat functions. Discharge depressions receive more groundwater inflow than they deliver to receiving landscapes. Because groundwater usually contains dissolved minerals, these wetlands often have soils that feature accumulations of minerals such as calcium. Due to storage capacity, discharge depressions can maintain downstream baseflow functions. Similar to slope wetlands, the discharge rate increases with increasing precipitation and infiltration. Depressional wetlands with no surface water connection usually provide habitat for amphibians that is free from fish predation. Depressional wetlands can cycle dissolved nitrogen, serve as a sink for phosphorous, and provide for other cycling of nutrients and compounds functions (NRCS 2008).

Depressional wetland values—Due to the provision of habitat for waterfowl, depressional wetlands are attributed hunting and subsistence use values.

Lacustrine Fringe Wetlands occur adjacent to lakes where the water elevation of the lake maintains the water table in the wetland. In some cases, they develop as a mat of floating vegetation attached to land. Additional sources of water are precipitation and groundwater discharge, the latter dominating where lacustrine fringe wetlands intergrade with uplands or slope wetlands. Surface water flow is bidirectional, usually controlled by water level fluctuations such as seiches (i.e., the building of water on the downwind shoreline during high wind events), in the adjoining lake. Lacustrine fringe wetlands may be indistinguishable from depressional wetlands, where the size of the lake becomes so small relative to fringe wetlands that the lake is incapable of stabilizing water tables. Lacustrine fringe wetlands lose water by flow returning to the lake after flooding, by overland flow, and by evapotranspiration. Organic matter normally accumulates in areas sufficiently protected from shoreline wave erosion.

Lacustrine fringe wetland vegetation—These wetlands are of limited extent in the analysis area. They are predominantly represented by the herbaceous NWI groups and the wet herbaceous and open low-shrub project vegetation types. In the analysis area, lacustrine fringe wetlands occur as freshwater marshes and peatlands bordering lakes.

Lacustrine fringe wetland functions—Functionally, lacustrine fringe wetlands are similar to estuarine fringe wetlands, except that they are freshwater, and their water level fluctuations are longer term and can be more extreme. Lacustrine fringe wetlands adjacent to lakes with relative stable water levels sequester organic carbon in the soil. During storm and flood events, lacustrine wetlands can provide attenuation of high flow, and can cycle nutrients and compounds delivered to the systems by floodwaters. Because lacustrine fringe wetlands provide a diverse array of hydrologic regimes, from deep water to surface saturation, they maintain habitat for a variety of wildlife species, including fish, waterfowl, and freshwater shellfish. In many cases, the maintenance of lake fisheries is dependent on lacustrine fringe wetlands for habitat during critical life-cycle periods (NRCS 2008).

Lacustrine fringe wetland values—Lakes and their associated wetlands are highly valued by residents of and visitors to the Bristol Bay region. In a largely roadless area, Iliamna Lake provides transportation and critical habitat for subsistence and commercial resources. Therefore, lakes and lacustrine wetlands are often the focal point of communities with high recreational, economic, subsistence, and heritage value.

Coastal Fringe Wetlands occur along protected coastlines, lagoons, and estuaries under tidal influence. The most extensive systems develop at the outlets of large rivers, where the unidirectional flow of freshwater gives way to the ebb and flow of tides. Here, river channel flow and tidal exchange are common water sources, with additional inputs from groundwater discharge and precipitation. Because coastal fringe wetlands frequently flood, and water table elevations are controlled mainly by sea level, they are seldom dry for significant periods. Coastal fringe wetlands lose water by tidal exchange, by overland flow to tidal creek channels, and by evapotranspiration. Organic matter normally accumulates in higher-elevation marsh areas where flooding is less frequent, and the wetlands are isolated from shoreline wave erosion by intervening areas of low marsh.

Coastal fringe wetland vegetation—Coastal fringe wetlands are an uncommon HGM wetland type in the analysis area and are exclusively represented by the herbaceous NWI group type and the halophytic wet graminoid meadow and halophytic dry graminoid project vegetation types (listed in decreasing order of representation). Occurrence of coastal fringe wetlands in the analysis area is limited to the coastline at Diamond Point.

Coastal fringe wetland functions—Because of the continuous maintenance of water levels provided by tides, sheltered coastal fringe wetlands are able to sequester organic carbon in their soils. Nutrients and compounds carried in river and stream water are cycled in coastal wetlands as flow slows before entering the ocean. Tidal and storm surge attenuation is provided as water enters and leaves through stable tidal channels. Coastal fringe wetlands provide a diverse array of hydrologic regimes, from deeper open water to surface saturation, which provides diverse habitat for a variety of wildlife species, including fish, waterfowl, and shellfish (NRCS 2008).

Coastal fringe wetland values—Coastal wetlands are dynamic and productive habitats that support a variety of subsistence resources. As an uncommon component of the broader coastal landscape, they are attributed high aesthetic, recreational, and uniqueness value. Due to the increased variability of coastal processes in the context of a changing climate, coastal fringe wetlands are ascribed additional value for the opportunities for education and scientific research they provide.

Other waters in the analysis area provide numerous ecosystem functions, including support for a wide array of anadromous and resident fish, aquatic invertebrates, birds, and mammals. Habitat characterizations are provided in the baseline reports (ABR 2011a; R2 Resource Consultants et al. 2011); Section 3.23, Wildlife Values; Section 3.24, Fish Values; and Section 3.25, Threatened and Endangered Species. Marine and freshwater waterbodies function to mitigate and retain storm and floodwater flows are additionally valued for recreation, hunting, fishing, and navigation opportunities.

Marine/Estuarine Waters—Cook Inlet provides habitat for many marine mammals, including Steller's sea lion (*Eumetopias jubatus*), harbor seal (*Phoca vitulina*), northern sea otter (*Enhydra lutris kenyoni*), beluga whale (*Delphinapterus leucas*), and gray whale (*Eschrichtius robustus*); and various bird species. Nearshore and estuarine habitats have been investigated at the Amakdedori and Diamond Point port analysis areas (GeoEngineers 2018a; Pentec Environmental/Hart Crowser 2011a, b). Several habitat types were identified, including mudflats and vegetated shallows. Mudflats, a special aquatic site described in the preceding subsection, provide resources for varying life stages of numerous fish and invertebrates, including chum, pink, and coho salmon (*Oncorhynchus keta, O. gorbuscha, O. kisutch*), Pacific herring (*Clupea pallasii*), and Pacific razor clam (*Siliqua patula*), Alaska surf clam (*Spisula solidissima*), and cockle species (*Clinocardium* spp.) (Ellanna and Wheeler 1989). Vegetated shallows, a special aquatic site supporting submerged aquatic vegetation, provide food and habitat for species, as well as maintaining water quality by absorbing nutrients, trapping sediments, reducing erosion, and producing oxygen.

Nearshore habitats are used as rearing areas, migration corridors, spawning areas, and places of refuge from deepwater predators. Essential services of estuaries include provision of food, habitat complexity, buffering from extreme forces of open waters, filtration, sediment trapping, and refuge from predation, which make them prime rearing or "nursery" habitats for numerous species of juvenile fish and invertebrates (Hughes et al. 2014). These habitat functions support values important to subsistence, commercial, and sport harvests.

Lakes/Ponds—Freshwater open waterbodies in the EIS analysis area range from very small ponds to large lakes (approximately 150 acres) and Iliamna Lake (1,000 square miles). The majority of waterbodies of this type in the EIS analysis area are less than 2.5 acres in size (ABR 2011a). There is a great variety in depth and hydrologic regime, shoreline complexity, and connectivity to drainages, all of which influence functions and values.

In general, these habitats have been identified as having relatively high species richness for bird and mammal species, including bird species of conservation concern (ABR 2011a), which is a characteristic of regionally important wetlands. Some species associated with these habitats include tundra swan (*Cygnus columbianus*), long-tailed duck (*Clangula hyemalis*), common loon (*Gavia immer*), arctic tern (*Sterna paradisaea*), river otter (*Lontra canadensis*), and moose (*Alces alces*). Iliamna Lake provides habitat to a population of freshwater seals, which are believed to be harbor seals (*Phoca vitulina*), although the exact species identification remains uncertain. These seals are unique in that freshwater seal populations are very rare in the northern hemisphere (VanLanen 2012). The wood frog (*Lithobates sylvaticus*) is the only amphibian that occurs in the analysis area, and is highly associated with deeper lakes and ponds (deeper than 5 feet). Some of the larger lakes provide spawning habitat for sockeye salmon. Water impounded by lakes and ponds is also important for maintaining summer flows and downstream aquatic habitat (R2 et al. 2011).

Rivers/Streams—Functions and values of these habitats vary greatly in the EIS analysis area depending on hydrologic regimes, bed and bank structure, floodplain interactions, and other fluvial processes. The relatively undisturbed nature of the watersheds means that floodplain processes, sediment and woody debris dynamics, and surface and groundwater exchanges are unencumbered, which has resulted in a large diversity of aquatic and riparian habitats in the EIS analysis area. This habitat diversity is responsible for the correspondingly large population and genetic diversity of salmonids in the wider Bristol Bay basin (Rinella et al. 2018). This in turn has been recognized as contributing to the high productivity and stability of these systems for salmonids (Schindler et al. 2010).

Streams in the EIS analysis area support five species of anadromous Pacific salmon, at least four species of non-anadromous salmonids, and numerous non-salmonid fishes (R2 Resource Consultants et al. 2011). Streams provide migration, spawning, rearing, and overwintering habitats for fish and invertebrate species. These habitat functions support values represented by importance to subsistence, commercial, and sport fisheries. Streams maintain characteristic riparian plant communities and export organic matter to support aquatic food chains. Riparian trees and shrubs provide shade to regulate stream temperatures and contribute large woody debris, which is important for channel-forming processes and creation of fish habitat. Aquatic and riparian habitats also have high value for bird and mammal species, including harlequin duck (*Histrionicus histrionicus*), bald eagle (*Haliaeetus leucocephalus*), arctic tern, river otter, brown bear (*Ursus arctos)*, and beaver (*Castor canadensis*). Streams also facilitate enrichment of riparian and terrestrial ecosystems with marine-derived nitrogen and other nutrients through the return of spawning salmon. Stream systems in the EIS analysis area also convey and attenuate flood waters, maintain and purify surface waters, moderate groundwater flows, and recharge groundwater systems.

3.22.8 Alternative 1a

The Alternative 1a analysis area is 20,553 acres, and includes the direct and indirect footprints for all project components; no variants are considered under this alternative (Table 3.22-4). Wetlands, a special aquatic site, compose 17 percent of this area; an additional 6 percent of the analysis area is other waters, including 184.7 miles of streams. Quantifiable types of wetlands identified as regionally important and other special aquatic sites individually represent 1 percent or less of the Alternative 1a analysis area; slope wetlands are the dominant HGM class. The types and areas of wetlands and other waters in the Alternative 1a analysis area are presented by project component in the following subsections.

3.22.8.1 Mine Site

The Alternative 1a analysis area for the mine site is predominantly in the Headwaters Koktuli River watershed, with a smaller portion in the Upper Talarik Creek watershed.[3] The Headwaters Koktuli River watershed drains the NFK and SFK rivers, which flow into Bristol Bay via the Mulchatna and Nushagak rivers (Figure 3.22-2). The landscape is composed of glaciated, volcanic-ash–influenced hills and valleys that are free of permafrost. Human-caused disturbance at the mine site is minimal and appears to be limited to all-terrain vehicle (ATV) trails, campsites, and exploration activity. Drill pads and other temporary disturbance from project exploration were not observed to alter wetland status or characteristics (Three Parameters Plus and HDR 2011b).

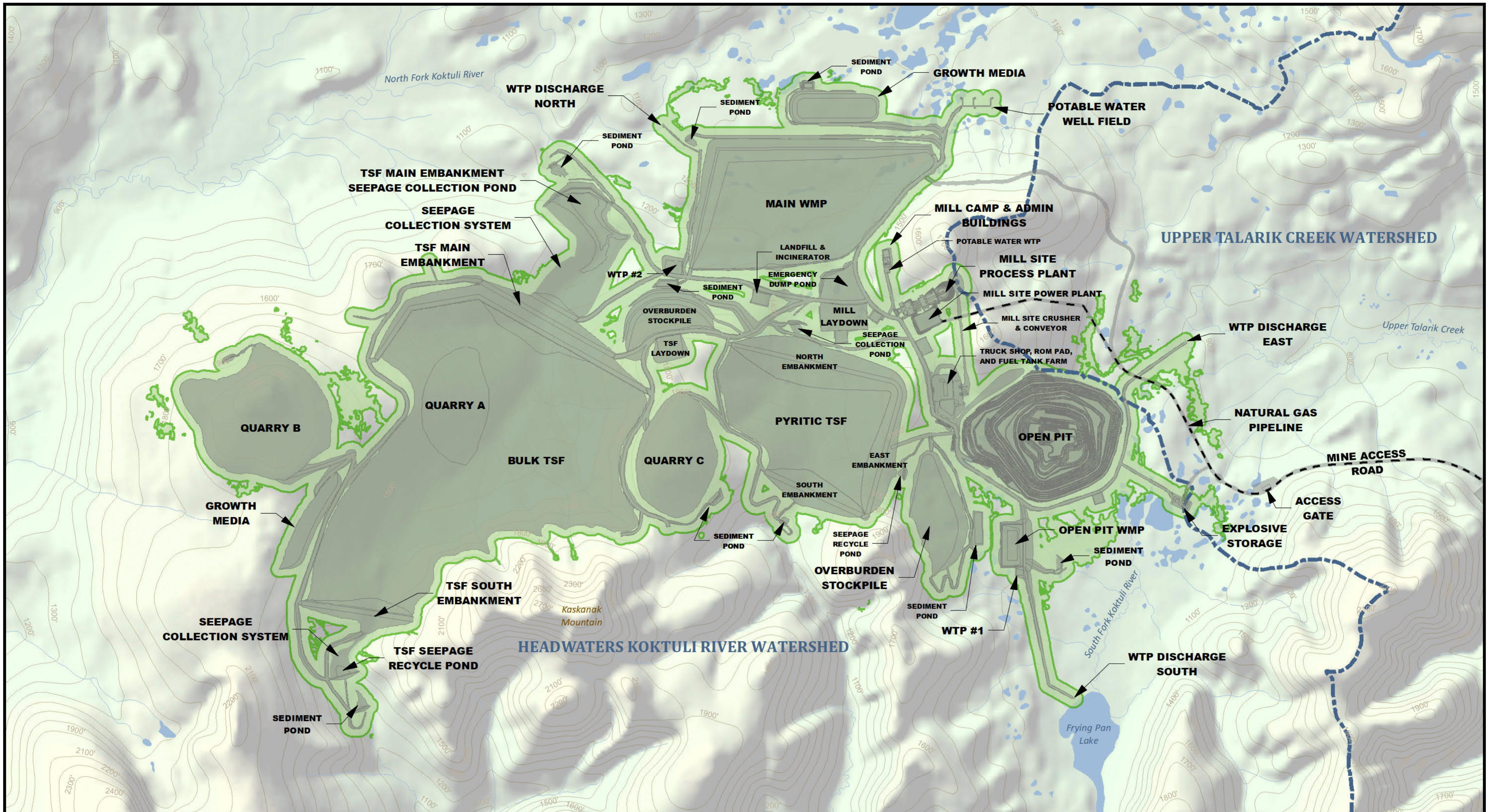
The mine site analysis area under Alternative 1a is 11,937 acres. Uplands represent 73 percent of the mine site, with the remaining 27 percent of the area composed of wetlands and other waters (Table 3.22-5). Of the wetland types present, the broad-leaved deciduous shrub type is dominant at 17 percent, with herbaceous wetlands subdominant at 8 percent. Both wetland types occur primarily as the slope HGM class, and secondarily as the riverine HGM class. Due to elevation and exposure, forested wetlands are absent at the mine site. Of the other water types present, ponds are the most abundant type at 1 percent of the mine site analysis area. A total of 132.9 miles of streams is present in the mine site analysis area. Community-level descriptions of wetland types, and the functions and values associated with HGM classes, are presented in the preceding sections.

[3]Watersheds are presented at the hydrologic unit code (HUC) 10 scale.

Table 3.22-4: Summary of Wetlands, Other Waters, Regionally Important Wetlands, Special Aquatic Sites, and HGM Classes by Area for Alternative 1a

Alternative 1a	Area (Acres)	Length (Miles)	Area (%)
Wetlands	3,588		17
Other Waters	1,293	184.7	6
Uplands	15,672		76
Total Wetlands and Other Waters	4,881		24
Alternative Analysis Area	20,553		100
Special Aquatic Sites			
Wetlands	3,588		17
Mudflats	40		<1
Vegetated Shallows	4		<1
Riffle and Pool Complexes	101	149.7	<1
Regionally Important Wetlands			
Fens	141		1
Forested Wetlands	13		<1
Riverine Wetlands	226		1
Estuarine Wetlands	-		-
Hydrogeomorphic Classes			
Slope	3,445		17
Depressional	174		1
Flat	37		<1
Lacustrine	246		1
Lacustrine Fringe	9		<1
Riverine Channel	115	184.7	1
Riverine	227		1
Coastal Fringe	-		-
Marine	646		3

Source: Three Parameters Plus and HDR 2011b; HDR and Three Parameters Plus 2011b; HDR 2019a, i



Sources: PLP 2019-RFI153

US Army Corps of Engineers

0.5 0 0.5 1

Miles

Mine Site Analysis Area

Alternative 1a

Natural Gas Pipeline

Mine Site/Transportation

Other Features

River/Stream

Lake/Pond

Watershed

100' Contour (Existing)

MINE SITE WETLANDS ANALYSIS AREA

PEBBLE PROJECT EIS

FIGURE 3.22-2

Table 3.22-5: Alternative 1a Analysis Area—Mine Site Wetland and Other Water Types

NWI Wetland Group	HGM Wetland Type								Total Area (Acres)	Total Length (Miles)	Total Area (%)
	Slope	Depressional	Flat	Lacustrine	Lacustrine Fringe	Riverine Channel	Riverine	Upland			
Herbaceous	833	14	4	—	8	—	77	—	937	—	**8**
Deciduous Shrub	1,902	12	11	—	1	—	112	—	2,038	—	**17**
Evergreen Shrub	13	—	—	—	—	—	—	—	13	—	**<1**
Aquatic Bed	2	—	—	—	—	—	—	—	2	—	**<1**
Ponds	30	86	—	—	—	<1	16	—	132	—	**1**
Lakes	—	—	—	15	—	—	—	—	15	—	**<1**
Streams (Intermittent)	—	—	—	—	—	5	<1	—	5	21.1	**<1**
Streams (Perennial)	—	—	—	—	—	57	—	—	57	111.8	**<1**
Upland	—	—	—	—	—	—	—	8,738	8,738	—	**73**
Total Wetlands and Other Waters (Acres)	**2,780**	**112**	**15**	**15**	**9**	**62**	**206**	**—**	**3,199**	**132.9**	**27**
Total Area (Acres)	**2,780**	**112**	**15**	**15**	**9**	**62**	**206**	**8,738**	**11,937**	**—**	**100**
Total Area (%)	**23**	**1**	**<1**	**<1**	**<1**	**1**	**2**	**73**	**100**		

Notes:
HGM = Hydrogeomorphic
NWI = National Wetland Inventory
Source: Three Parameters Plus and HDR 2011b; HDR and Three Parameters Plus 2011b; HDR 2019a, i

3.22.8.2 Transportation Corridor

The Alternative 1a analysis area for the transportation corridor includes the 35 miles of the mine site access road from the mine site to the Eagle Bay ferry terminal, with a connection to the existing Iliamna/Newhalen road system, a 28-mile crossing of Iliamna Lake to the south ferry terminal, and a 37-mile port access road between the lake and Amakdedori port. It also includes the Kokhanok spur road connecting the transportation corridor to the community of Kokhanok and the explosives storage spur road connecting the mine site access road to a storage pad near the mine site. The transportation corridor includes the segments of the natural gas pipeline that are co-located with road alignments. This alternative includes a southern crossing of the Newhalen River and a crossing of the Gibraltar River.

The transportation corridor is dominated by glaciated, volcanic ash-influenced mountains, hills, plains, and valleys that are free from permafrost. Human-caused disturbance in the transportation corridor is minimal, and appears to be limited to ATV trails, roads, and building pads near the village of Iliamna, Kokhanok Airport, and the shore of Iliamna Lake. Disturbances were not observed to alter wetland status or characteristics (Three Parameters Plus and HDR 2011b).

The transportation corridor crosses the Bristol Bay and Cook Inlet drainage basins; in the Cook Inlet drainage basin, the Amakdedori Creek-Kamishak Bay watershed[4] is the only watershed crossed by the transportation corridor. The watersheds intersected by the transportation corridor in the Bristol Bay drainage basin include the UTC, Newhalen River, Iliamna Lake, and Gibraltar Lake watersheds.

The Alternative 1a transportation corridor analysis area is 7,494 acres. Uplands represent 89 percent of the transportation corridor, with the remaining 11 percent of the area composed of wetlands and other waters (Table 3.22-6). Of the wetland types present, the broad-leaved deciduous shrub type is dominant at 5 percent, and herbaceous wetlands are subdominant at 2 percent. Both wetland types occur primarily as the slope HGM class, with broad-leaved deciduous shrub wetlands also occurring as the riverine HGM class. Forested wetlands account for less than 1 percent of the Alternative 1a transportation corridor. Of the other water types present, ponds are dominant at 2 percent of the transportation corridor; the remaining other water types represent less than 1 percent each of the analysis area. A total of 51.1 miles of streams is present in the transportation corridor analysis area. Community-level descriptions of wetland types, and the functions and values associated with HGM classes, are presented in the preceding sections.

3.22.8.3 Amakdedori Port

The Alternative 1a analysis area for the Amakdedori port comprises 118 acres of undisturbed habitat on the shore of Kamishak Bay near Amakdedori Creek. The port is in the Amakdedori Creek-Kamishak Bay watershed in the Cook Inlet drainage. Topography is generally flat, with dunes located closer to the gravel beach shoreline of Cook Inlet; eelgrass beds are not present in the Alternative 1a analysis area (see Section 3.24, Fish Values).

Uplands represent 82 percent of the port site, with the remaining 18 percent of the area composed of wetlands and other waters (Table 3.22-7). Herbaceous wetlands are the only wetland type represented, and are associated primarily with riverine, and secondarily with slope HGM classes. Of the other water types present, marine waters (both intertidal and subtidal) are dominant at 15 percent combined. Community-level descriptions of wetland types, and the functions and values associated with HGM classes, are presented in the preceding sections.

[4] Watersheds are presented at the hydrologic unit code (HUC) 10 scale.

Table 3.22-6: Alternative 1a Analysis Area—Transportation Corridor Wetland and Other Water Types

NWI Wetland Group	HGM Wetland Type								Total Area (Acres)	Total Length (Miles)	Total Area (%)
	Slope	Depressional	Flat	Lacustrine	Lacustrine Fringe	Riverine Channel	Riverine	Upland			
Herbaceous	156	9	8	—	<1	—	3	—	176	—	**2**
Deciduous Shrub	316	1	6	—	<1	—	15	—	339	—	**5**
Evergreen Shrub	48	2	—	—	—	—	—	—	50	—	**1**
Deciduous Forest	11	—	—	—	—	—	1	—	12	—	**<1**
Evergreen Forest	<1	—	—	—	—	—	—	—	<1	—	**<1**
Aquatic Bed	<1	1	—	—	<1	—	<1	—	1	—	**<1**
Ponds	102	47	—	—	—	—	1	—	150	—	**2**
Lakes	—	—	—	74	—	—	—	—	74	—	**1**
Streams (Intermittent)	—	—	—	—	—	2		—	2	13.8	**<1**
Streams (Perennial)	<1	—	—	—	—	48	<1	—	48	37.2	**1**
Upland	—	—	—	—	—	—	—	6,642	6,642	—	**89**
Total Wetlands and Other Waters (Acres)	**634**	**60**	**15**	**74**	**<1**	**50**	**20**	**—**	**852**	**51.1**	**11**
Total Area (Acres)	**634**	**60**	**15**	**74**	**<1**	**50**	**20**	**6,642**	**7,494**	—	**100**
Total Area (%)	**8**	**1**	**<1**	**1**	**<1**	**1**	**<1**	**89**	**100**		

Notes:
-- = not applicable
HGM = Hydrogeomorphic
NWI = National Wetland Inventory
Source: Three Parameters Plus and HDR 2011b; HDR and Three Parameters Plus 2011b; HDR 2019a, i

Table 3.22-7: Alternative 1a Analysis Area—Amakdedori Port Wetland and Other Water Types

NWI Wetland Group	HGM Wetland Type					Total Area (Acres)	Total Length (Miles)	Total Area (%)
	Slope	Riverine Channel	Riverine	Marine	Upland			
Herbaceous	1		<1	—	—	1	—	**1**
Streams (Perennial)	—	3	—	—	—	3	0.1	**2**
Marine (Intertidal)	—	—	—	9	—	9	—	**7**
Marine (Subtidal)	—	—	—	9	—	9	—	**8**
Upland	—	—	—	—	97	97	—	**82**
Total Wetlands and Other Waters (Acres)	**1**	**3**	**<1**	**18**	**—**	**22**	**0.1**	**18**
Total Area (Acres)	**1**	**3**	**<1**	**18**	**97**	**118**	**—**	**100**
Total Area (%)	**1**	**2**	**<1**	**15**	**82**	**100**		

Notes:
— = not applicable
HGM = Hydrogeomorphic
NWI = National Wetland Inventory
Source: Three Parameters Plus and HDR 2011b; HDR and Three Parameters Plus 2011b; HDR 2019a, ii

3.22.8.4 Natural Gas Pipeline Corridor

Under Alternative 1a, the natural gas pipeline corridor includes five main segments: 1) Cook Inlet crossing to the Amakdedori port; 2) along the port access road to Iliamna Lake; 3) across Iliamna Lake to Newhalen; 4) overland to connect with the mine access road east of the Newhalen River crossing; and 5) along the mine access road to the mine site.

Segments of the natural gas pipeline corridor adjacent to access roads are addressed under the transportation corridor analysis area. Stand-alone segments of the natural gas pipeline (i.e., those that are not co-located with road corridors) are addressed here, and include overland stand-alone segments to tie-in to project facilities (13 miles), the Cook Inlet crossing (104 miles), and the Iliamna Lake crossing (21 miles). Cook Inlet is characterized by nearshore and deepwater habitats with unconsolidated sediments on a smooth bottom, and strong tidal currents. Numerous tributary basins with active glaciers contribute to high suspended sediment load in portions of Cook Inlet. Iliamna Lake is almost entirely deepwater habitat with an unconsolidated bottom.

The Alternative 1a analysis area for the natural gas pipeline corridor is 1,007 acres. Uplands represent 20 percent of the analysis area, with the remaining 80 percent of the area composed of wetlands and other waters (Table 3.22-8). Of the wetland types present, the broad-leaved deciduous shrub and herbaceous types are codominant at 1 percent each. Both wetland types occur primarily as slope, and secondarily as flat HGM classes. Of the other water types present, subtidal marine waters are dominant at 62 percent; lakes are subdominant at 16 percent. Community-level descriptions of wetland types, and the functions and values associated with HGM classes, are presented in the preceding sections.

3.22.9 Alternative 1

The Alternative 1 analysis area is 21,860 acres, and includes the direct and indirect footprints for all project components, as well as the Summer-Only Ferry Operations, Kokhanok East Ferry Terminal, and Pile-Supported Dock variants (Table 3.22-9). Wetlands, a special aquatic site, comprise 17 percent of this area; an additional 6 percent of the analysis area is other waters, including 189.0 miles of streams. Quantifiable types of wetlands, identified as regionally important, and other special aquatic sites represent 1 percent or less of the Alternative 1 analysis area; slope wetlands are the dominant HGM class. The types and areas of wetlands and other waters in the Alternative 1 analysis area are presented by project component in the following subsections.

Table 3.22-8: Alternative 1a Analysis Area—Natural Gas Pipeline Corridor Wetland and Other Water Types

NWI Wetland Group	HGM Wetland Type								Total Area (Acres)	Total Length (Miles)	Total Area (%)
	Slope	Depressional	Flat	Lacustrine	Riverine Channel	Riverine	Marine	Upland			
Herbaceous	3	1	2	—	—	<1	—	—	6	—	**1**
Deciduous Shrubs	5	<1	4	—	—	1	—	—	10	—	**1**
Evergreen Shrubs	3		2	—	—	—	—	—	5	—	**<1**
Evergreen Forest	—	—	—	—	—	<1	—	—	<1	—	**<1**
Aquatic Bed	—	<1	—	—	—	—	—	—	<1	—	**<1**
Ponds	—	<1	—	—	—	—	—	—	<1	—	**<1**
Lakes	—	—	—	157	—	—	—	—	157	—	**16**
Streams (Intermittent)	—	—	—	—	<1	—	—	—	<1	0.1	**<1**
Streams (Perennial)	—	—	—	—	<1	—	—	—	<1	0.5	**<1**
Marine (Intertidal)	—	—	—	—	—	—	1	—	1	—	**<1**
Marine (Subtidal)	—	—	—	—	—	—	628	—	628	—	**62**
Upland	—	—	—	—	—	—	—	200	200	—	**20**
Total Wetlands and Other Waters (Acres)	**11**	**2**	**8**	**157**	**<1**	**2**	**628**	**—**	**808**	**0.6**	**80**
Total Area (Acres)	**11**	**2**	**8**	**157**	**<1**	**2**	**628**	**200**	**1,007**	**—**	**100**
Total Area (%)	**1**	**<1**	**1**	**16**	**<1**	**<1**	**62**	**20**	**100**		

Notes:
— = not applicable
HGM = Hydrogeomorphic
NWI = National Wetland Inventory
Source: Three Parameters Plus and HDR 2011b; HDR and Three Parameters Plus 2011b; HDR 2019a, i

Table 3.22-9: Summary of Wetlands, Other Waters, Regionally Important Wetlands, Special Aquatic Sites, and HGM Classes by Area for the Alternative 1 Analysis Area

Alternative 1	Area (Acres)	Length (Miles)	Area (%)
Wetlands	3,623	—	17
Other Waters	1,392	189.0	6
Uplands	16,845	—	77
Total Wetlands and Other Waters	5,015	—	23
Total Alternative Analysis Area	21,860	—	100
Special Aquatic Sites			
Wetlands	3,623	—	17
Mudflats	52	—	<1
Vegetated Shallows	3	—	<1
Riffle and Pool Complexes	91	150.9	<1
Regionally Important Wetlands			
Fens	142	—	1
Forested Wetlands	3	—	<1
Riverine Wetlands	242	—	1
Estuarine Wetlands	—	—	—
Hydrogeomorphic Classes			
Slope	3,458	—	16
Depressional	196	—	1
Flat	53	—	<1
Lacustrine	286	—	1
Lacustrine Fringe	9	—	<1
Riverine Channel	109	189.0	<1
Riverine	242	—	1
Coastal Fringe	—	—	—
Marine	683	—	3

Notes:
— = not applicable
HGM = Hydrogeomorphic
Source: Three Parameters Plus and HDR 2011b; HDR and Three Parameters Plus 2011b; HDR 2019a, i

3.22.9.1 Mine Site

The mine site analysis area under Alternative 1 is 11,955 acres. Uplands represent 73 percent of the mine site, with the remaining 27 percent of the area composed of wetlands and other waters (Table 3.22-10). Of the wetland types present, the broad-leaved deciduous shrub type is dominant at 17 percent; herbaceous wetlands are subdominant at 8 percent. Both wetland types occur primarily as the slope HGM class, and secondarily as the riverine HGM class. Due to elevation and exposure, forested wetlands are absent at the mine site. Of the other water types present, ponds are the most abundant type at 1 percent of the mine site analysis area. A total of 132.9 miles of streams is present in the mine site analysis area. Community-level descriptions of wetland types, and the functions and values associated with HGM classes, are presented in the preceding sections.

Summer-Only Ferry Operations Variant

This variant would restrict operation of the ferry across Iliamna Lake to the open water season. Instead of daily transportation to the Amakdedori port, concentrate would be stored in a container-based system that would be stockpiled at the mine site during the period when the lake is frozen. The containers would be stored in a laydown area at the mine site, requiring relocation of the sewage tank pad. This change in configuration would increase the area of direct disturbance at the mine site by 33 acres, thereby increasing the area of the affected environment for wetlands and other waters. This increase is included in the Alternative 1 analysis area for the mine site, presented in Table 3.22-10.

3.22.9.2 Transportation Corridor

The Alternative 1 transportation corridor includes 28 miles of the mine access road from the mine site to a ferry terminal on the north shore of Iliamna Lake; a 18-mile ferry crossing of Iliamna Lake from the north ferry terminal to the south ferry terminal west of Kokhanok; and the port access road considered under Alternative 1a. Separate spur roads included under Alternative 1 are the 9-mile Iliamna spur road from the mine access road to the existing road system supporting the communities of Iliamna and Newhalen, and the Kokhanok spur road and explosives storage spur road described under Alternative 1a. The transportation corridor includes the segments of the natural gas pipeline that are co-located with road alignments. This alternative includes a crossing of the Gibraltar River.

The transportation corridor analysis area under Alternative 1 is 8,820 acres. Uplands represent 89 percent of the area, with the remaining 11 percent of the area composed of wetlands and other waters (Table 3.22-11). Of the wetland types present, the broad-leaved deciduous shrub type is dominant at 4 percent, herbaceous wetlands are subdominant at 2 percent, and the evergreen shrub type represents an additional 1 percent. All three wetland types occur primarily as the slope HGM class. Forested wetlands account for less than 1 percent of the transportation corridor analysis area. No additional wetland types are represented. Of the other water types present, ponds are dominant at 2 percent, with lakes subdominant at 1 percent. A total of 55.7 miles of streams is present in the transportation corridor analysis area. Community-level descriptions of wetland types, and the functions and values associated with HGM classes, are presented in the preceding sections.

Table 3.22-10: Alternative 1 Analysis Area—Mine Site Wetland and Other Water Types

NWI Wetland Group	HGM Wetland Type								Total Area (Acres)	Total Length (Miles)	Total Area (%)
	Slope	Depressional	Flat	Lacustrine	Lacustrine Fringe	Riverine Channel	Riverine	Upland			
Herbaceous	833	14	4	—	8	—	77	—	937	—	**8**
Deciduous Shrub	1,902	12	11	—	1	—	112	—	2,038	—	**17**
Evergreen Shrub	13	—	—	—	—	—	—	—	13	—	**<1**
Aquatic Bed	2	—	—	—	—	—	—	—	2	—	**<1**
Ponds	30	86	—	—	—	<1	16	—	132	—	**1**
Lakes	—	—	—	15	—	—	—	—	15	—	**<1**
Streams (Intermittent)	—	—	—	—	—	5	<1	—	5	21.1	**<1**
Streams (Perennial)	—	—	—	—	—	57	—	—	57	111.8	**<1**
Upland	—	—	—	—	—		—	8,756	8,756	—	**73**
Total Wetlands and Other Waters (Acres)	**2,780**	**112**	**15**	**15**	**9**	**62**	**206**	**—**	**3,199**	**132.9**	**27**
Total Area (Acres)	**2,780**	**112**	**15**	**15**	**9**	**62**	**206**	**8,756**	**11,955**	**—**	**100**
Total Area (%)	**23**	**1**	**<1**	**<1**	**<1**	**1**	**2**	**73**	**100**		

Notes:
— = not applicable
HGM = Hydrogeomorphic
NWI = National Wetland Inventory

Source: Three Parameters Plus and HDR 2011b; HDR and Three Parameters Plus 2011b; HDR 2019a, i

Table 3.22-11: Alternative 1 Analysis Area—Transportation Corridor Wetland and Other Water Types

NWI Wetland Group	HGM Wetland Type								Total Area (Acres)	Total Length (Miles)	Total Area (%)
	Slope	Depressional	Flat	Lacustrine	Lacustrine Fringe	Riverine Channel	Riverine	Upland			
Herbaceous	164	16	13	—	<1	—	5	—	199		**2**
Deciduous Shrub	322	3	18	—	—	—	27	—	370		**4**
Evergreen Shrub	48	1	6	—	—	—	—	—	55		**1**
Deciduous Forest	2	—	—	—	—	—	<1	—	2		**<1**
Evergreen Forest	—	—	1	—	—	—	—	—	1		**<1**
Aquatic Bed	1	<1	—	—	<1	—	<1	—	1		**<1**
Ponds	116	63	—	—	—	—	1	—	179		**2**
Lakes	—	—	—	93	—	—	—	—	93		**1**
Streams (Intermittent)	—	—	—	—	—	3	—	—	3	17.0	**<1**
Streams (Perennial)	—	—	—	—	—	38	—	—	38	38.7	**<1**
Upland	—	—	—	—	—	—	—	7,880	7,880		**89**
Total Wetlands and Other Waters (Acres)	**652**	**82**	**38**	**93**	**<1**	**40**	**34**	**—**	**940**	**55.7**	**11**
Total Area (Acres)	**652**	**82**	**38**	**93**	**<1**	**40**	**34**	**7,880**	**8,820**	**—**	**100**
Total Area (%)	**7**	**1**	**<1**	**1**	**<1**	**<1**	**<1**	**89**	**100**		

Notes:
— = not applicable
HGM = Hydrogeomorphic
NWI = National Wetland Inventory
Source: Three Parameters Plus and HDR 2011b; HDR and Three Parameters Plus 2011b; HDR 2019a, i

Kokhanok East Ferry Terminal Variant

This variant considers an alternate south ferry terminal site east of Kokhanok, thereby avoiding a crossing of the Gibraltar River and reducing the overall number of stream crossings. It includes a 27-mile-long crossing of Iliamna Lake and a 27-mile port access road from the Kokhanok East ferry terminal to Amakdedori port on Cook Inlet. Spur roads included under this variant are the 5-mile Kokhanok spur road connecting the port access road to the community of Kokhanok, and the Iliamna and explosives storage spur roads described under Alternative 1a. Increase to the extent of the affected environment for wetlands and other waters is captured in the Alternative 1 analysis area for the transportation corridor, presented in Table 3.22-11.

3.22.9.3 Amakdedori Port

Uplands represent 65 percent of the port site, with the remaining 35 percent of the area composed of wetlands and other waters (Table 3.22-12). Herbaceous wetlands are the dominant wetland type represented (2 percent), and are associated primarily with riverine, and secondarily with slope HGM classes. Of the other water types present, marine waters (both intertidal and subtidal) are dominant at 30 percent combined. Community-level descriptions of wetland types, and the functions and values associated with HGM classes, are presented in the preceding sections.

3.22.9.4 Summer-Only Ferry Operations Variant

Under this variant, concentrate would be transported to the port site during the operating months and stored in an expanded container storage yard. Construction of this storage yard would increase the area of direct disturbance at the port by approximately 28 acres. Increase to the affected environment for wetlands and other waters is captured in the Alternative 1 analysis area for the Amakdedori port, presented in Table 3.22-12.

Pile-Supported Dock Variant

This variant proposes an alternate pile-supported dock design at Amakdedori port, which would reduce the footprint of direct disturbance by 11 acres. The area of the affected environment for wetlands and other waters is captured in the Alternative 1 analysis area for the Amakdedori port, presented in Table 3.22-12.

3.22.9.5 Natural Gas Pipeline Corridor

The Alternative 1 natural gas pipeline corridor includes four main segments: 1) Cook Inlet crossing to the Amakdedori port; 2) along the port access road to the south ferry terminal; 3) across Iliamna Lake to the north ferry terminal; and 4) along the mine access road to the mine site.

Segments of the natural gas pipeline corridor adjacent to access roads are addressed under the transportation corridor for Alternative 1. Stand-alone segments of the natural gas pipeline (i.e., those that are not co-located with road corridors) are addressed here, and include overland stand-alone segments to tie-in to project facilities (5 miles), the Cook Inlet crossing (104 miles), and the Iliamna Lake crossing (19 miles).

The natural gas pipeline corridor analysis area under Alternative 1 is 900 acres. Uplands represent 10 percent of the analysis area, with the remaining 90 percent of the area composed of wetlands and other waters (Table 3.22-13). Broad-leaved deciduous shrub and herbaceous are the only wetland types present, and are co-dominant at less than 1 percent each. Both wetland types occur primarily as slope, and secondarily as riverine HGM classes. Of the other water types present, subtidal marine waters are dominant at 70 percent, lakes are subdominant at 20 percent. The natural gas pipeline analysis area contains 0.2 mile of streams. Community-level descriptions of wetland types, and the functions and values associated with HGM classes, are presented in the preceding sections.

Table 3.22-12: Alternative 1 Analysis Area—Amakdedori Port Wetland and Other Water Types

NWI Wetland Group	HGM Wetland Type					Total Area (Acres)	Total Length (Miles)	Total Area (%)
	Slope	Riverine Channel	Riverine	Marine	Upland			
Herbaceous	1		2	—	—	3		**2**
Deciduous Shrubs	<1		<1	—	—	<1		**<1**
Streams (Perennial)	—	7	—	—	—	7	0.2	**4**
Marine (Intertidal)	—	—	—	9	—	9		**5**
Marine (Subtidal)	—	—	—	45	—	45		**25**
Upland	—	—	—	—	120	120		**65**
Total Wetlands and Other Waters (Acres)	**1**	**7**	**2**	**54**	**—**	**65**	**0.2**	**35**
Total Area (Acres)	**1**	**7**	**2**	**54**	**120**	**185**		**100**
Total Area (%)	**1**	**4**	**1**	**29**	**65**	**100**		

Notes:
— = not applicable
HGM = Hydrogeomorphic
NWI = National Wetland Inventory
Source: Three Parameters Plus and HDR 2011b; HDR and Three Parameters Plus 2011b; HDR 2019a, i

Table 3.22-13: Alternative 1 Analysis Area—Natural Gas Pipeline Corridor Wetland and Other Water Types

NWI Wetland Group	HGM Wetland Type							Total Area (Acres)	Total Length (Miles)	Total Area (%)
	Slope	Depressional	Lacustrine	Riverine Channel	Riverine	Marine	Upland			
Herbaceous	2	—	—	—	<1	—	—	2		**<1**
Deciduous Shrubs	2	—	—	—	<1	—	—	2		**<1**
Ponds	—	<1	—	—	—	—	—	<1		**<1**
Lakes	—	—	178		—	—	—	178		**20**
Streams (Intermittent)	—	—	—	<1	—	—	—	<1	0.1	**<1**
Streams (Perennial)	—	—	—	<1	—	—	—	<1	0.1	**<1**
Marine (Intertidal)	—	—	—	—	—	1	—	1		**<1**
Marine (Subtidal)	—	—	—	—	—	628	—	628		**70**
Upland	—	—	—	—	—	—	90	90		**10**
Total Wetlands and Other Waters (Acres)	**4**	**<1**	**178**	**<1**	**<1**	**628**	**—**	**810**	**0.2**	**90**
Total Area (Acres)	**4**	**<1**	**178**	**<1**	**<1**	**628**	**90**	**900**		**100**
Total Area (%)	**0**	**<1**	**20**	**<1**	**<1**	**70**	**10**	**100**		

Note:
Less than 0.1 acre of Streams and less than 1 acre of Ponds are present in the analysis area for this alternative
— = not applicable
HGM = Hydrogeomorphic
NWI = National Wetland Inventory
Source: Three Parameters Plus and HDR 2011b; HDR and Three Parameters Plus 2011b; HDR 2019a, i

Kokhanok East Ferry Terminal Variant

Under the Kokhanok East Ferry Terminal Variant, the natural gas pipeline alignment from the Amakdedori port would follow the port access road towards the Kokhanok East ferry terminal and the spur road into Kokhanok. From Kokhanok, it would follow an existing road alignment to the point where it departs the shoreline to tie into the route from the Kokhanok west ferry terminal site. The total pipeline length with this variant would be approximately 2 miles less than the Alternative 1 base case but would increase the crossing of Iliamna Lake by 1 mile. Change to the affected environment for wetlands and other waters is captured in the Alternative 1 analysis area for the natural gas pipeline, presented in Table 3.22-13.

3.22.10 Alternative 2—North Road and Ferry with Downstream Dams

The Alternative 2 analysis area is 20,515 acres, and includes the direct and indirect footprints for all project components, as well as the Summer-Only Ferry Operations, Newhalen River North Crossing, and Pile-Supported Dock variants (Table 3.22-14). Wetlands, a special aquatic site, comprise 17 percent of this area; an additional 7 percent of the analysis area is other waters, including 180.0 miles of streams. Quantifiable wetland types identified as regionally important and other special aquatic sites represent 1 percent or less of the Alternative 2 analysis area. The types and HGM classes of wetlands and other waters are summarized by area and presented by project component below.

3.22.10.1 Mine Site

The downstream dam construction method proposed for the Alternative 2 mine site increases direct disturbance footprint by 107 acres relative to Alternative 1a, Alternative 1, and Alternative 3, thereby increasing the affected environment for wetlands and other waters. The mine site analysis area under Alternative 2 is 12,052 acres. Uplands represent 73 percent of the mine site, with the remaining 27 percent of the area made up of wetlands and other waters (Table 3.22-15). Of the wetland types present, the broad-leaved deciduous shrub type is dominant at 17 percent; herbaceous wetlands are subdominant at 8 percent. Both wetland types occur primarily as the slope HGM class, and secondarily as the riverine HGM class. Due to elevation and exposure, forested wetlands are absent at the mine site. Of the other water types present, ponds are the most abundant type at 1 percent of the mine site analysis area. A total of 133.4 miles of streams is present in the mine site analysis area. Community-level descriptions of wetland types, and the functions and values associated with HGM classes, are presented in the preceding sections.

Summer-Only Ferry Operations Variant

The Summer-Only Ferry Variant would increase the area of direct disturbance at the mine site by 33 acres associated with a container storage yard and relocation of a sewage tank pad, thereby increasing the extent of the affected environment for wetlands and other waters. This increased size is included in the Alternative 2 analysis area for the mine site presented in Table 3.22-15.

3.22.10.2 Transportation Corridor

The Alternative 2 transportation corridor includes 35 miles of the mine access road from the mine site to the Eagle Bay ferry terminal on the northern shore of Iliamna Lake, a 29-mile crossing of the lake to the Pile Bay ferry terminal, and an 18-mile port access road connecting the Pile Bay terminal to the Diamond Point port on Cook Inlet. This alternative includes a southern crossing of the Newhalen River. The transportation corridor includes the segments of the natural gas pipeline that are co-located with road alignments.

Table 3.22-14: Summary of Wetlands, Other Waters, Regionally Important Wetlands, Special Aquatic Sites, and HGM Classes by Area for the Alternative 2 Analysis Area

Alternative 2	Area (Acres)	Length (Miles)	Area (%)
Wetlands	3,407	—	17
Other Waters	1,370	180.0	7
Uplands	15,738	—	77
Total Wetlands and Other Waters	4,776	—	23
Total Alternative Analysis Area	20,515	—	100
Special Aquatic Sites			
Wetlands	3,406	—	17
Mudflats	136	—	1
Vegetated Shallows	3	—	<1
Riffle and Pool Complexes	147	147.5	1
Regionally Important Wetlands			
Fens	140	—	1
Forested Wetlands	28	—	<1
Riverine Wetlands	259	—	1
Estuarine Wetlands	4	—	<1
Hydrogeomorphic Classes			
Slope	3,131	—	15
Depressional	161	—	1
Flat	30	—	<1
Lacustrine	67	—	<1
Lacustrine Fringe	11	—	<1
Riverine Channel	181	180.0	1
Riverine	263	—	1
Coastal Fringe	331	—	2
Marine	618	—	3

Notes:
— = not applicable
HGM = Hydrogeomorphic
NWI = National Wetland Inventory

Source: Three Parameters Plus and HDR 2011b; HDR and Three Parameters Plus 2011b; HDR 2019a, i

Table 3.22-15: Alternative 2 Analysis Area—Mine Site Wetland and Other Water Types

NWI Wetland Group	HGM Wetland Type								Total Area (Acres)	Total Length (Miles)	Total Area (%)
	Slope	Depressional	Flat	Lacustrine	Lacustrine Fringe	Riverine Channel	Riverine	Upland			
Herbaceous	845	14	4	—	8	—	77	—	948		**8**
Deciduous Shrub	1,909	12	11	—	1	—	112	—	2,044		**17**
Evergreen Shrub	13	—	—	—	—	—	—	—	13		**<1**
Aquatic Bed	2	—	—	—	—	—	—	—	2		**<1**
Ponds	30	86	—	—	—	<1	16	—	132		**1**
Lakes	—	—	—	15	—	—	—	—	15		**<1**
Streams (Intermittent)	—	—	—	—	—	5	<1	—	5	21.1	**<1**
Streams (Perennial)	—	—	—	—	—	58	—	—	58	112.2	**<1**
Upland	—	—	—	—	—	—	—	8,835	8,835		**73**
Total Wetlands and Other Waters (Acres)	**2,799**	**112**	**15**	**15**	**9**	**62**	**206**	**—**	**3,217**	**133.4**	**27**
Total Area (Acres)	**2,799**	**112**	**15**	**15**	**9**	**62**	**206**	**8,835**	**12,052**	**—**	**100**
Total Area (%)	**23**	**1**	**<1**	**<1**	**<1**	**1**	**2**	**73**	**100**		

Notes:
— = not applicable
HGM = Hydrogeomorphic
NWI = National Wetland Inventory
Source: Three Parameters Plus and HDR 2011b; HDR and Three Parameters Plus 2011b; HDR 2019a, i

The transportation corridor analysis area under Alternative 2 is 5,788 acres. Uplands represent 88 percent of the analysis area, with the remaining 12 percent of the area made up of wetlands and other waters (Table 3.22-16). Of the wetland types present, the broad-leaved deciduous shrub type is dominant at 4 percent; herbaceous wetlands are subdominant at 2 percent. Both wetland types occur primarily as the slope HGM class, and to a lesser extent as the riverine HGM class. Of the other water types present, subtidal estuarine waters and perennial streams are codominant at 2 percent each. A total of 34.1 miles of streams is present in the transportation corridor analysis area, including 0.2 mile of tidally influenced river. Community-level descriptions of wetland types, and the functions and values associated with HGM classes, are presented in the preceding sections.

Summer-Only Ferry Operations Variant

Under this variant, concentrate shipping at the Diamond Point port would continue per the year-round schedule even though the Iliamna Lake ferry operations would be restricted to the open water season. To support shipping from Diamond Point port, a 22-acre container storage area would be located along the Williamsport-Pile Bay Road; the remote location is due to limited space at Diamond Point port. The increase in the extent of the affected environment for wetlands and other waters related to the storage area is included in the Alternative 2 analysis area for the transportation corridor, presented in Table 3.22-16.

Newhalen River North Variant

This variant includes an alternative crossing of the Newhalen River north of the proposed location and would increase the direct disturbance footprint by 20 acres; mainly attributed to material sites. This increase in the affected environment for wetlands and other waters is included in the analysis area for the Alternative 2 transportation corridor, presented in Table 3.22-16.

3.22.10.3 Diamond Point Port

The Diamond Point port analysis area under Alternative 2 is composed of 255 acres of relatively undisturbed habitat at the juncture of Iliamna and Cottonwood bays. The Diamond Point Quarry is adjacent to the proposed port location, and the Williamsport-Pile Bay Road terminates at the head of Iliamna Bay. Coastal habitats in the Alternative 2 Diamond Point port analysis area include sand and pebble substrates interspersed by rocky reefs and mudflats. Eelgrass beds are not known to occur in the Alternative 2 Diamond Point port analysis area (see Section 3.24, Fish Values). The nearshore environment at Diamond Point is shallow, and would therefore require initial and maintenance dredging of 58 acres for access to the dock. Dredged material would be disposed of onshore in two bermed storage facilities. Both the area of dredging and the areas of storage facilities are included in the port analysis area. Dredging activities are more fully described in Chapter 2, Alternatives; locations of the proposed dredge area and storage areas for dredged materials are shown in Figure 2-71. Uplands represent 46 percent of the Diamond Point port analysis area, with the remaining 54 percent of the area composed of wetlands and other waters (Table 3.22-17). Estuarine intertidal wetlands are the dominant wetland type at 3 percent; herbaceous wetlands represent an additional 1 percent. These wetland types are exclusively associated with the coastal fringe HGM class. Of the other water types present, subtidal estuarine waters are overwhelmingly dominant at 50 percent. A total of 0.8 mile of streams is present in the port analysis area; 0.7 mile of this total is intermittent, and the remaining 0.2 mile is perennial. Community-level descriptions of wetland types, and the functions and values associated with HGM classes, are presented in the preceding sections.

Table 3.22-16: Alternative 2 Analysis Area—Transportation Corridor Wetland and Other Water Types

NWI Wetland Group	HGM Wetland Type									Total Area (Acres)	Total Length (Miles)	Total Area (%)
	Slope	Depressional	Flat	Lacustrine	Lacustrine Fringe	Riverine Channel	Riverine	Coastal Fringe	Upland			
Herbaceous	57	15	8	—	<1	—	18	3	—	100		**2**
Deciduous Shrub	170	4	6	—	<1	—	23	—	—	204		**4**
Evergreen Shrub	19	2	—	—	—	—	—	—	—	21		**<1**
Deciduous Forest	11	<1	—	—	—	—	3	—	—	14		**<1**
Evergreen Forest	5		—	—	—	—	1	—	—	7		**<1**
Aquatic Bed	<1	1	—	—	—	—	<1	—	—	1		**<1**
Ponds	9	26	—	—	—	—	5	—	—	39		**1**
Lakes	—	—	—	38	—	—	—	—	—	38		**1**
Streams (Intermittent)	—	—	—	—	—	9		—	—	9	**8.4**	**<1**
Streams (Perennial)	<1	—	—	—	—	94	<1	—	—	94	**25.4**	**2**
Rivers/Streams (Tidal)	—	—	—	—	—	<1		1	—	1	**0.2**	**<1**
Estuarine (Intertidal)	—	—	—	—	—	—	—	69	—	69		**1**
Estuarine (Subtidal)	—	—	—	—	—	—	—	89	—	89		**2**
Upland	—	—	—	—	—	—	—	—	5,102	5,102		**88**
Total Wetlands and Other Waters (Acres)	**271**	**47**	**15**	**38**	**<1**	**104**	**49**	**162**	**—**	**686**	**34.1**	**12**
Total Area (Acres)	**271**	**47**	**15**	**38**	**<1**	**104**	**49**	**162**	**5,102**	**5,788**		**100**
Total Area (%)	**5**	**1**	**<1**	**1**	**<1**	**2**	**1**	**3**	**88**	**100**		

Notes:
— = not applicable
HGM = Hydrogeomorphic
NWI = National Wetland Inventory

Source: Three Parameters Plus and HDR 2011b; HDR and Three Parameters Plus 2011b; HDR 2019a, i; stream miles included parenthetically.

Table 3.22-17: Alternative 2 Analysis Area—Diamond Point Port Wetland and Other Water Types

NWI Wetland Group	HGM Wetland Type			Total Area (Acres)	Total Length (Miles)	Total Area (%)
	Riverine Channel	Coastal Fringe	Upland			
Herbaceous	—	1	—	1		**1**
Streams (Intermittent)	2	—	—	2	0.7	**1**
Streams (Perennial)	<1	—	—	<1	0.2	**<1**
Estuarine (Intertidal)	—	8	—	8		**3**
Estuarine (Subtidal)	—	127	—	127		**50**
Upland	—	—	116	116		**46**
Total Wetlands and Other Waters (Acres)	**2**	**137**	**—**	**139**	**0.8**	**54**
Total Area (Acres)	**2**	**137**	**116**	**255**		**100**
Total Area (%)	**1**	**54**	**46**	**100**		

Notes:
— = not applicable
HGM = Hydrogeomorphic
NWI = National Wetland Inventory
Source: Three Parameters Plus and HDR 2011b; HDR and Three Parameters Plus 2011b; HDR 2019a, i

Pile-Supported Dock Variant

This variant would reduce the direct disturbance footprint by 11 acres. The extent of the affected environment for wetlands and other waters is captured in the Alternative 2 analysis area for the Diamond Point port, presented in Table 3.22-17.

3.22.10.4 Natural Gas Pipeline Corridor

The Alternative 2 natural gas pipeline corridor includes three main segments: 1) Cook Inlet crossing coming ashore at Ursus Cove; 2) northward to Diamond Point port; and 3) overland to the mine site, following along the port and mine access roads with a stand-alone segment between.

Segments of the natural gas pipeline corridor adjacent to access roads are addressed under the transportation corridor. Stand-alone segments of the natural gas pipeline (i.e., those that are not co-located with road corridors) are addressed here, and include overland stand-alone segments to tie-in to project facilities (44 miles), the Cook Inlet crossing (75 miles), and the Cottonwood Bay crossing (3 miles). The area also encompasses construction access roads to the natural gas pipeline corridor on the northern side of Iliamna Lake.

The natural gas pipeline corridor analysis area under Alternative 2 is 2,419 acres. Uplands represent 70 percent of the analysis area, with the remaining 30 percent of the area comprising wetlands and other waters (Table 3.22-18). Of the wetland types present, the broad-leaved deciduous shrub and herbaceous types are co-dominant at 1 percent each. Both wetland types occur primarily as slope, and secondarily as riverine HGM classes. Of the other water types present, subtidal marine waters are overwhelmingly dominant at 26 percent. A total of 11.6 miles of streams is present in the natural gas pipeline analysis area. Community-level descriptions of wetland types, and the functions and values associated with HGM classes, are presented in the preceding sections.

Table 3.22-18: Alternative 2 Analysis Area—Natural Gas Pipeline Corridor Wetland and Other Water Types

NWI Wetland Group	HGM Wetland Type									Total Area (Acres)	Total Length (Miles)	Total Area (%)
	Slope	Depressional	Lacustrine	Lacustrine Fringe	Riverine Channel	Riverine	Coastal Fringe	Marine	Upland			
Herbaceous	10	1	—	<1	—	4	—	—	—	15		**1**
Deciduous Shrubs	27	<1	—	1	—	3	—	—	—	32		**1**
Evergreen Shrubs	1	—	—	—	—	—	—	—	—	1		**<1**
Deciduous Forest	6	—	—	—	—	<1	—	—	—	6		**<1**
Evergreen Forest	1	—	—	—	—	<1	—	—	—	1		**<1**
Aquatic Bed	—	—	—	—	—	<1	—	—	—	<1		**<1**
Ponds	<1	<1	—	—	—	<1	—	—	—	1		**<1**
Lakes	—	—	14	—	—	—	—	—	—	14		**1**
Streams (Intermittent)	—	—	—	—	1	—	—	—	—	1	2.0	**<1**
Streams (Perennial)	—	—	—	—	13	—	—	—	—	13	9.6	**1**
Estuarine (Intertidal)	—	—	—	—	—	—	7	—	—	7		**<1**
Estuarine (Subtidal)	—	—	—	—	—	—	25	—	—	25		**1**
Marine (Intertidal)	—	—	—	—	—	—	—	1	—	1		**<1**
Marine (Subtidal)	—	—	—	—	—	—	—	618	—	618		**26**
Upland	—	—	—	—	—	—	—	—	1,685	1,685		**70**
Total Wetlands and Other Waters (Acres)	**45**	**2**	**14**	**2**	**14**	**8**	**32**	**618**	**—**	**734**	**11.6**	**30**
Total Area (Acres)	**45**	**2**	**14**	**2**	**14**	**8**	**32**	**618**	**1,685**	**2,419**		**100**
Total Area (%)	**2**	**<1**	**1**	**<1**	**1**	**<1**	**1**	**26**	**70**	**100**		

Notes:
— = not applicable
HGM = Hydrogeomorphic
NWI = National Wetland Inventory

Source: Three Parameters Plus and HDR 2011b; HDR and Three Parameters Plus 2011b; HDR 2019a, i

3.22.11 Alternative 3—North Road Only

The Alternative 3 analysis area is 21,684 acres and includes the direct and indirect footprints for all project components and the Concentrate Pipeline Variant (Table 3.22-19). Wetlands, a special aquatic site, comprise 16 percent of this area; an additional 6 percent of the analysis area is other waters, including 190.4 miles of streams. Quantifiable types of wetlands identified as regionally important and other special aquatic sites represent 1 percent or less of the Alternative 3 analysis area; slope wetlands are the dominant HGM class. The types and HGM classes of wetlands and other waters are summarized by area and presented by project component below.

Table 3.22-19: Summary of Wetlands, Other Waters, Regionally Important Wetlands, Special Aquatic Sites, and HGM Classes by Area for the Alternative 3 Analysis Area

Alternative 3	Area (Acres)	Length (Miles)	Area (%)
Wetlands	3,454	—	16
Other Waters	1,300	190.4	6
Uplands	16,929	—	78
Total Wetlands and Other Waters	4,754	—	22
Total Alternative Analysis Area	21,684	—	100
Special Aquatic Sites			
Wetlands	3,454	—	16
Mudflats	115	—	1
Vegetated Shallows	3	—	<1
Riffle and Pool Complexes	160	156.7	1
Regionally Important Wetlands			
Fens	140	—	1
Forested Wetlands	34	—	<1
Riverine Wetlands	274	—	1
Estuarine Wetlands	3	—	<1
Hydrogeomorphic Classes			
Slope	3,158	—	15
Depressional	167	—	1
Flat	33	—	<1
Lacustrine	64	—	<1
Lacustrine Fringe	11	—	<1
Riverine Channel	193	190.4	1
Riverine	279	—	1
Coastal Fringe	297	—	1
Marine	569	—	3

Notes:
— = not applicable
HGM = Hydrogeomorphic
Source: Three Parameters Plus and HDR 2011b; HDR and Three Parameters Plus 2011b; HDR 2019a, i

3.22.11.1 Mine Site

The mine site analysis area under Alternative 3 is the same as Alternative 1a, a summary of which is presented in Table 3.22-5.

3.22.11.2 Concentrate Pipeline Variant

This variant considers delivery of concentrate to Diamond Point port via a pipeline, and includes an option to construct an additional pipeline to return filtrate to the mine site for reuse. This variant would increase the direct disturbance footprint at the mine site by 1 acre for an electric pump station. Due to the configuration of facilities, this increase does not result in an increase to the Alternative 3 mine site analysis area.

3.22.11.3Transportation Corridor

The Alternative 3 transportation corridor includes the 82-mile north access road from the mine site to a port location north of Diamond Point in Iliamna Bay. This alternative includes a realignment from the Alternative 2 natural gas pipeline corridor around Knutson Bay on Iliamna Lake and a southern crossing of the Newhalen River. The transportation corridor analysis area includes the sections of the natural gas pipeline that are co-located with roads.

The transportation corridor analysis area under Alternative 3 is 8,757 acres. Uplands represent 91 percent of the transportation corridor, with the remaining 9 percent of the area composed of wetlands and other waters (Table 3.22-20). Of the wetland types present, the broad-leaved deciduous shrub type is dominant at 3 percent; herbaceous wetlands are subdominant at 2 percent, and estuarine intertidal habitat represent an additional 1 percent. The broad-leaved deciduous shrub and herbaceous wetland types occur primarily as the slope HGM class, and secondarily as the riverine HGM class, while estuarine intertidal wetlands are exclusively associated with the coastal fringe HGM class. Of the other water types present, estuarine subtidal, lakes, ponds, and perennial streams each represent 1 percent of the analysis area. A total of 54.2 miles of streams is present in the transportation corridor analysis area. Community-level descriptions of wetland types, and the functions and values associated with HGM classes, are presented in the preceding sections.

Concentrate Pipeline Variant

This variant would slightly increase the road corridor width due to the co-location of the concentrate pipeline and the optional return water pipeline in a single trench with the natural gas pipeline. Construction of the concentrate pipeline would increase the average width of the road corridor by less than 10 percent; construction of both the concentrate and water return pipelines would increase the average width of the road corridor by less than 3 feet. The length would be the same as the overland portion of the natural gas pipeline. An intermediate booster station would be sited in a material site along the road alignment. The increase in road alignment width associated with this variant does not result in an increase in the transportation corridor analysis area for Alternative 3, presented in Table 3.22-20.

3.22.11.4Port

Alternative 3 proposes a caisson dock design at a port site north of Diamond Point in Iliamna Bay. Due to the shallowness of Iliamna Bay, dredging would be required at this port location. Bulk concentrate would be lightered by barges out to Handysize bulk carriers at a mooring point in Iniskin Bay. There would not be an alternate lightering location under Alternative 3.

Table 3.22-20: Alternative 3 Analysis Area—Transportation Corridor Wetland and Other Water Types

NWI Wetland Group	HGM Wetland Type									Total Area (Acres)	Total Length (Miles)	Total Area (%)
	Slope	Depressional	Flat	Lacustrine	Lacustrine Fringe	Riverine Channel	Riverine	Coastal Fringe	Upland			
Herbaceous	85	12	11	—	2	—	27	3	—	139		**2**
Deciduous Shrub	229	3	7	—	<1	—	36	—	—	275		**3**
Evergreen Shrub	13	<1	—	—	—	—	—	—	—	13		**<1**
Deciduous Forest	21	—	—	—	—	—	4	—	—	25		**<1**
Evergreen Forest	8	—	—	—	—	—	<1	—	—	8		**<1**
Aquatic Bed	—	1	—	—	—	—	<1	—	—	1		**<1**
Ponds	2	39	—	—	—	<1	5	—	—	46		**1**
Lakes	—	—	—	49	—	—	—	—	—	49		**1**
Streams (Intermittent)	—	—	—	—	—	10	—	—	—	10	11.5	**<1**
Streams (Perennial)	<1	—	—	—	—	117	—	—	—	117	42.5	**1**
Streams (Tidal)	—	—	—	—	—	<1	—	1	—	1	0.2	**<1**
Estuarine (Intertidal)	—	—	—	—	—	—	—	63	—	63		**1**
Estuarine (Subtidal)	—	—	—	—	—	—	—	65	—	65		**1**
Upland	—	—	—	—	—	—	—	—	7,945	7,945		**91**
Total Wetlands and Other Waters (Acres)	**357**	**54**	**18**	**49**	**2**	**128**	**72**	**131**	**—**	**811**	**54.2**	**9**
Total Area (Acres)	**357**	**55**	**18**	**49**	**3**	**128**	**72**	**131**	**7,945**	**8,757**		**100**
Total Area (%)	**4**	**1**	**<1**	**1**	**<1**	**1**	**1**	**1**	**91**	**100**		

Notes:
— = not applicable
HGM = Hydrogeomorphic
NWI = National Wetland Inventory
Source: Three Parameters Plus and HDR 2011b; HDR and Three Parameters Plus 2011b; HDR 2019a, i

The port analysis area under Alternative 3 comprises 160 acres of relatively undisturbed habitat in Iliamna Bay. There is a quarry at Diamond Point, and the Williamsport-Pile Bay Road terminates at the head of Iliamna Bay. Coastal habitats in the Alternative 3 port analysis area include sand and pebble substrates interspersed by rocky reefs and mudflats. Eelgrass beds are not known to occur in the Alternative 3 port analysis area (see Section 3.24, Fish Values). Initial and maintenance dredging would be required over 76 acres of estuarine habitat; dredged material would be stored in one of two facilities in uplands along the port access road. Both the areas of dredging and dredged material storage facilities are included in the port analysis area.

Uplands represent 42 percent of the port analysis area, with the remaining 58 percent of the area composed of wetlands and other waters (Table 3.22-21). Estuarine waters are the dominant habitat type at 57 percent, and are exclusively associated with the coastal fringe HGM class. A total of 0.4 mile of streams is present in the port analysis area. Community-level descriptions of wetland types, and the functions and values associated with HGM classes, are presented in the preceding sections.

Concentrate Pipeline Variant

This variant would require concentrate handling, dewatering, and treatment facilities at Diamond Point port. Port operations would change due to the requirements of dewatering the concentrate, storing water and concentrate, and treating and discharging the filtrate water; however, the overall footprint of the port is only expected to increase by less than 1 acre (approximately 0.3 acre); attributed to the placement of three caissons in the dredge basin to provide mooring and loading for concentrate lightering barges. This increase in the marine facility footprint does not result in an increase in the port analysis area for Alternative 3, as presented in Table 3.22-21.

3.22.11.5Natural Gas Pipeline Corridor

The Alternative 3 natural gas pipeline corridor analysis area would follow the entire north road access route from the port to the mine site. Relative to Alternative 2, this co-location with the road places much of the natural gas pipeline in the transportation corridor analysis area. Stand-alone segments of the natural gas pipeline (i.e., those that are not co-located with road alignments) are addressed here and include overland stand-alone segments to tie-in to project facilities (8 miles), the Cook Inlet crossing (75 miles), and the Cottonwood Bay crossing (3 miles). The Alternative 3 natural gas pipeline corridor analysis area includes intertidal estuarine habitat in Cottonwood Bay, the unvegetated portions of which are considered mudflats, a special aquatic site.

The natural gas pipeline corridor analysis area under Alternative 3 is 830 acres. Uplands represent 22 percent of the analysis area, with the remaining 78 percent of the area consisting of wetlands and other waters (Table 3.22-22). Of the wetland types present, the broad-leaved deciduous shrub and intertidal estuarine habitat are co-dominant at 1 percent each. Of the other water types present, subtidal marine waters are overwhelmingly dominant at 69 percent. A total of 2.9 miles of streams is present in the natural gas pipeline analysis area. Community-level descriptions of wetland types, and the functions and values associated with HGM classes, are presented in the preceding sections.

Table 3.22-21: Alternative 3 Analysis Area—Port Wetland and Other Water Types

NWI Wetland Group	HGM Wetland Type					Total Area (Acres)	Total Length (Miles)	Total Area (%)
	Flat	Riverine Channel	Riverine	Coastal Fringe	Upland			
Deciduous Shrubs	<1	—	<1	—	—	1		**<1**
Streams (Intermittent)	—	1	—	—	—	1	0.3	**<1**
Streams (Perennial)	—	<1	—	—	—	<1	0.1	**<1**
Estuarine (Intertidal)	—	—	—	<1	—	<1		**<1**
Estuarine (Subtidal)	—	—	—	92	—	92		**57**
Upland	—	—	—	—	67	67		**42**
Total Wetlands and Other Waters (Acres)	**<1**	**1**	**<1**	**92**		**93**	**0.4**	**58**
Total Area (Acres)	**<1**	**1**	**<1**	**92**	**67**	**160**		**100**
Total Area (%)	**<1**	**1**	**<1**	**57**	**42**	**100**		

Notes:
— = not applicable
HGM = Hydrogeomorphic
NWI = National Wetland Inventory

Source: Three Parameters Plus and HDR 2011b; HDR and Three Parameters Plus 2011b; HDR 2019a, i

Table 3.22-22: Alternative 3 Analysis Area—Natural Gas Pipeline Corridor Wetland and Other Water Types

NWI Wetland Group	HGM Wetland Type							Total Area (Acres)	Total Length (Miles)	Total Area (%)
	Slope	Depressional	Riverine Channel	Riverine	Coastal Fringe	Marine	Upland			
Herbaceous	1	—	—	<1	—	—	—	1		**<1**
Deciduous Shrubs	4	—	—	<1	—	—	—	4		**1**
Ponds	<1	<1		—	—	—	—	<1		**<1**
Rivers/Streams (Intermittent)	—	—	<1	—	—	—	—	<1	0.5	**<1**
Rivers/Streams (Perennial)	—	—	2	—	—	—	—	2	2.4	**<1**
Estuarine (Intertidal)	—	—	—	—	6	—	—	6		**1**
Estuarine (Subtidal)	—	—	—	—	67	—	—	67		**8**
Marine (Intertidal)	—	—	—	—	—	1	—	1		**<1**
Marine (Subtidal)	—	—	—	—	—	569	—	569		**69**
Upland	—	—	—	—	—	—	180	180		**22**
Total Wetlands and Other Waters (Acres)	**5**	**<1**	**2**	**1**	**74**	**569**		**650**	**2.9**	**78**
Total Area (Acres)	**5**	**<1**	**2**	**1**	**74**	**569**	**180**	**830**		**100**
Total Area (%)	**1**	**<1**	**<1**	**<1**	**9**	**69**	**22**	**100**		

Notes:
— = not applicable
HGM = Hydrogeomorphic
NWI = National Wetland Inventory

Source: Three Parameters Plus and HDR 2011b; HDR and Three Parameters Plus 2011b; HDR 2019a, i

3.22.12 Climate Change

Climate change is currently affecting vegetation and wetlands in the EIS analysis area. Current and future effects on wetlands are tied to changes in physical resources and vegetation. Wetland trends observed in the Bristol Bay region are attributed in recent publications to warmer and wetter conditions, including rapid tree growth and expansion, new coastal wetlands, and changes in phenology (i.e., the cyclic and seasonal natural phenomena, especially in relation to climate and plant and animal life) (ANTHC 2018). Over the past few decades, the tundra and low ericaceous shrub environment in the vicinity of the project area have been replaced by alder and willow shrub (ANTHC 2018). On average in the last 50 years, in the southern two-thirds of Alaska lakes have decreased in area (Klein et al. 2005; Riordan et al. 2006; Roach et al. 2011; Rover et al. 2012). This is due to a combination of permafrost thaw, greater evaporation in a warmer climate, and increased soil organic accumulation during a longer season for plant growth (Chapin et al. 2014). However, in some places, lakes are becoming larger as a result of lateral permafrost degradation (Roach et al. 2011). Future permafrost thaw would likely increase lake area in areas of continuous permafrost and decrease lake area in places where the permafrost zone is more fragmented (Avis et al. 2011). Both wetland drying and the increased frequency of warm, dry summers and associated thunderstorms have led to more large fires in the last 10 years than in any decade since recordkeeping began in the 1940s (Kasischke et al. 2010). Wildland fires with burn intensities and depths capable of consuming vegetation and peat have the potential to significantly alter wetland function and hydrology.

Clark et al. (2010) evaluated the effects that a changing climate may have on key habitats in Alaska. Successional changes of wetland types is beginning to occur in some places; wetlands in northern Alaska are predicted to move toward wetland types currently existing in western Alaska, while western Alaska wetlands may tend towards interior Alaska wetland types. Increased temperatures, longer growing seasons, and warmer winters are likely to interact to create a drier, warmer climate in Alaska, because it seems unlikely that the projected increased precipitation would exceed evapotranspiration over the longer thawed periods (Hassol 2004). Overall, Alaska is likely to experience lower overall land coverage in wetlands and likely an increase in forested wetlands relative to more herbaceous types (Clark et al. 2010). Additional discussion on climate change trends on vegetation can be found in Section 3.26, Vegetation. Addition discussion on climate change trends on hydrology can be found in Section 3.16, Surface Water Hydrology.